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BULLETIN

OF THE

AMERICAN PHYSICAL SOCIETY

INCLUDING THE

PROGRAMME OF THE

1957 WINTER MEETING ON THE WEST COAST

AT

STANFORD UNIVERSITY, CALIFORNIA

December 19–20–21

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December 19, 1957 Ser. II, Vol. 2,No. 8

BULLETIN

OF THE

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1957 Winter Meeting in the West, Stanford University, Stanford, California, December 19–21, 1957

THE **1957 winter meeting on the Pacific Coast** will be held on the campus of Stanford University on Thursday, Friday, and Saturday, **December 19, 20, and 21.** Tradition has been violated in that the meeting will be held a week before Christmas instead of during the Christmas recess. This occurs because of the adjacent conference on nuclear sizes, also to be held at Stanford during the same week. It was felt that it would be better to have the two meetings as close together as is reasonable. This will be a week of what is probably the greatest concentration of physics meetings on the West Coast. The Nuclear Sizes meetings will be held on Tuesday, Wednesday, and Thursday, December 17, 18, and 19. On Monday, December 16, of the same week, there will be a symposium on Magnetohydrodynamics, arranged by the Lockheed Aircraft Corporation, Missiles Systems Division, in Palo Alto.

It is expected that a great many people will attend both the meeting on Nuclear Sizes and the American Physical Society meeting; therefore, alternate **living arrangements** have been made for those who will attend just the American Physical Society meeting and those who will attend both meetings. Requests for these reservations should be made to Dr. John M. Yarborough, Director of Residences, Stanford University, Stanford, California. For those individuals who plan to attend both meetings, combination living arrangements have been made. These will cost a total of $42.08 and will include dormitory housing from Monday through Saturday nights and meals beginning with breakfast on Tuesday, December 17, and ending with dinner on Saturday, the 21st. Two of the dinners are not included in this package because they are reserved for banquets for each of the two meetings. The members of our Society who are planning to attend only the Physical Society meeting will be charged $28.16 for accommodations. This will include dormitory housing from Wednesday through Saturday nights, December 17 through the 21st, all meals from breakfast on Thursday morning through Saturday evening dinner, but it does not include dinner on Friday night, which is reserved for the banquet of the Society.

Those individuals living "off campus" or staying at local hotels or motels, could, if they wish, make a **prepaid luncheon arrangement** for the three luncheons with either group or the five luncheons with both groups at a cost of $2.08 per luncheon or $6.24 for three, or $10.40 for the five. These campus lunches are for groups of three or five. "Single" lunches can be had only at the "Cellar," on campus, or off campus.

The Chairman of the Local Committee in charge of these arrangements is Professor S. D. Drell. Those desiring information on motel or hotel accommodations, other than residence halls, should write Professor Drell, who has prepared a mimeographed list of these accommodations.

Registration will be in the new Physics Lecture Hall, where many of the sessions will be held. This meeting is, in a way, a kind of inauguration for this beautiful new facility. Registration will begin at 8:30 Monday morning, and there will be the usual fee of $1.00. A bulletin board, message center, telephone, and conference rooms will be available. There will also be a registration desk for the ladies, where information for the ladies' program will be available.

Tickets for the banquet of the Society will be sold at the registration desk. The price is $3.50. The banquet of the Society will take place on Friday night at 7:30 P.M. at Rickey's Restaurant on El Camino Real. The principal speaker will be Dr. W. Shockley, Director of the Shockley Semiconductor Laboratories, who will talk on "Physicists, Dollars, and Sputnik." Professor L. I. Schiff, Chairman of the Department of Physics at Stanford, will be the presiding officer. Dean William C. Steere, Dean of the Graduate Division at Stanford, will greet the Society on behalf of the University.

The program consists of **149 contributed papers and 27 invited papers.** The usual parallel sessions are with us, nor was it possible to arrange them ideally. The invited paper session on Thursday afternoon (Session D) on Nuclear Structure is a joint program of the two meetings. The program has been arranged with the help of Professors S. D. Drell, L. I. Schiff, F. Bloch, R. Hofstadter, and N. L. Oleson.

Post-deadline papers of sufficient importance to warrant their inclusion in a special supplementary program will be considered by the Local Secretary if the abstracts are received no later than Monday, December 16, at the office of the Local Secretary for the Pacific Coast (see address below). These papers will be presented following sessions that will be designated on a blackboard near the registration desk.

W. A. NIERENBERG
Local Secretary for the Pacific Coast
Department of Physics
University of California
Berkeley 4, California

EPITOME OF THE 1957 STANFORD MEETING

(Personal names are those of invited speakers.)

Thursday Morning

9:30 A. Electron physics; Post, Graham, Dehmelt, Thomas, Crittenden. Dinkelspiel.*

10:00 B. Sound, hydrodynamics, and general physics; Griffith. Room 370.

9:30 C. Solid-state physics, I. Room 101.

Thursday Afternoon

2:00 D. Nuclear structure; Brueckner, Watson, Green, Bethe. Dinkelspiel.

1:30 E. Electron physics. Room 101.

Friday Morning

9:30 F. Field theory and experiments; Franken, Drell, Karplus, Chew. Room 100.

9:30 G. Low-energy nuclear physics, I. Room 370.

10:00 H. High-energy nuclear physics. Room 101.

Friday Afternoon

1:30 I. Parity; Yang, Goldhaber, Lederman, Stevenson, Schwartz. Dinkelspiel.

2:00 J. Low-energy nuclear physics, II. Room 370.

1:30 K. Nuclear and paramagnetic resonance. Room 101.

Friday Evening

7:30 Banquet of the American Physical Society; Shockley. Rickey's Restaurant.

Saturday Morning

10:00 L. Biophysics; Williams, Blois, Kaplan. Dinkelspiel.

9:30 M. Low-energy nuclear physics, III; Igo. Room 370.

9:30 N. Solid-state physics, II. Room. 101.

9:45 O. High-energy electron physics. Room 100.

Saturday Afternoon

1:30 P. Nuclear and paramagnetic resonance; Jen, Packard, Carver, Hahn. Room 100.

1:30 Q. Theory. Room 101.

1:30 R. Low-energy nuclear physics, IV. Room 370.

* Dinkelspiel is the Music Auditorium; Room 370 is in the Main Quadrangle; Rooms 100 and 101 are in the new Physics Lecture Building.

PROGRAMME

THURSDAY MORNING AT 9:30

Dinkelspiel*

(N. L. OLESON presiding)

Invited Papers on Electron Physics

A1. Radiation Processes in a High-Temperature Plasma. R. F. POST, *Radiation Laboratory, University of California, Livermore.* (30 min.)

A2. Magnetodynamic Phenomena in Steady-State Plasmas. W. J. GRAHAM, *Naval Research Laboratory.* (30 min.)

A3. Spin Resonance of Free Electrons Polarized by Exchange Collisions. H. G. DEHMELT, *University of Washington.* (30 min.)

A4. Recent Work on Surface Properties of Zinc Oxide. D. G. THOMAS, *Bell Telephone Laboratories.* (30 min.)

A5. Superconducting Phase Transition Times in Thin Films. E. C. CRITTENDEN, JR., *U. S. Naval Postgraduate School.* (30 min.)

THURSDAY MORNING AT 10:00

Room 370

(L. N. RIDENOUR presiding)

Sound, Hydrodynamics, and General Physics

Invited Paper

B1. Role of Dissociation Fluid Flow. W. C. GRIFFITH, *Research and Development Laboratory, Lockheed Missile System Division.* (30 min.)

Contributed Papers

B2. Liquid Rope-Coil Effect. GEORGE BARNES, *University of Nevada,* AND RICHARD WOODCOCK, *University of California Radiation Laboratory, Livermore.*—The tendency for a falling stream of very viscous liquid to coil like a rope when it strikes a horizontal surface is studied and the building of a "cone" of liquid of considerable height above the surface is observed. It is shown that, although the liquid stream as a whole appears to rotate about the axis of the cone, the particles of liquid do not actually rotate about this axis. Variations of the liquid rope-coil effect are discussed.

B3. Explosive Acceleration of Particles.* G. E. DUVALL, J. O. ERKMAN, AND C. M. ABLOW, *Stanford Research Institute.*—The terminal velocity of a small particle accelerated by a slab of explosive of finite thickness has been calculated with the following assumptions: (i) the force accelerating the particle is $KA\rho|u-v|^3$, where K is a drag coefficient ($=\frac{1}{2}$ for spheres), A is the cross section of the particle normal to its direction of motion, u and ρ are gas velocity and density at the particle position, and v is the instantaneous particle velocity; (ii) the flow field from the detonation is unperturbed by the presence of the particle; (iii) the detonation gases are polytropic with $\gamma=3$; (iv) the detonation is plane and normally incident on one bounding surface. Four cases have been considered: (a) the explosive is bounded on both faces by a void and the particle moves in the direction of detonation; (b) as in (a) but the particle is driven backward; (c) the explosive face at which detonation is initiated is a rigid boundary and the particle moves in the direction of detonation; (d) the face at which detonation is completed is a rigid boundary and the particle moves backward. The motion is described by an ordinary differential equation which has been integrated numerically. When explosive thickness increases indefinitely and the particle moves in the direction of detonation, its velocity approaches detonation velocity. When it moves in the opposite direction, it approaches one-half detonation velocity.

* Supported by the Ordnance Department, U. S. Army.

B4. Shock Twinning of Molybdenum.* JOHN J. KELLY AND PAUL S. DECARLI, *Stanford Research Institute* (introduced by G. E. Duvall).—The deformation markings appearing in the microstructure of iron after explosive loading have been variously described as crystallographic twins[1] formed by shock loading and as evidence of a pressure induced transformation similar to the temperature induced transformation known to exist for iron.[2] Experiments will be described which show that molybdenum, which exhibits no temperature induced transformation, contains the same type of deformation markings when explosively loaded. This was accomplished by subjecting a specimen to a converging cylindrical shock of intensity $\lesssim 270$ kilobars. The twins so formed appear generally as co-planar segments although some are completely transgranular. Thus far, only two directions per grain have been observed. Habit

* Dinkelspiel is the Music Auditorium; Room 370 is in the Main Quadrangle; Rooms 100 and 101 are in the new Physics Lecture Building.

plane and critical stress for twinning have not yet been determined.

* Work supported in part by the Office of Chief of Ordnance, U. S. Army.
[1] J. S. Rinehart, and J. Pearson, *Behavior of Metals Under Impulsive Loads*, (American Society for Metals, Cleveland, 1954).
[2] M. E. Nicholson, University of Minnesota (private communication).

B5. Magnetic Concentricity Gage. P. E. SEAWARD, J. W. DEMPSTER, AND T. C. POULTER, *Stanford Research Institute.*—The gage described in this paper consists of a magnetic circuit made from a surplus magnetron magnet and steel frame pieces with a suitable space wherein the shaped charge is rotated by an air motor and drive spindle. A sensitive pickup coil is located in line with the barrier near to the shaped charge. An electronic amplifier is used in conjunction with a vacuum tube voltmeter to give a measure of the magnitude of barrier offset. Other electronic circuitry is used with a flashlamp to indicate the position of maximum barrier eccentricity. This gage measures barrier offset over the range of 0.001 to 0.140 in. to an accuracy of 5 to 10% and it indicates the position of maximum eccentricity to within plus or minus 15°. Since the voltage induced in the pickup coil is a linear function of rotational speed and barrier eccentricity it was necessary to properly shape the amplifier frequency-response in order to remove this dependence on rotational speed over the range of speeds that the air motor is normally operated.

B6. Multiple Flash X-Ray Exposures. R. W. MCLEOD, *Stanford Research Institute* (introduced by W. B. Farrand).—The flash x-ray system has been used extensively in high explosive research as a means of viewing explosive phenomena in the presence of gas, smoke, and flame. Because of x-ray tube design and power requirements, the flash x-ray system is presently limited to a single flash per unit. To overcome this limitation several units are used with delayed triggering systems to obtain time-spaced radiographs. This method has required a separate film and cassette for each flash x-ray unit. A method has been devised utilizing a slit to divide the x-ray beams, which will allow two radiographs from separate units to be recorded on a single film. By a simple extension of this idea four radiographs of two similar charges on a single film may be obtained. By this system the reference problem for separate films is greatly simplified and the object-to-film distance can be reduced considerably. Analysis is facilitated by superimposing a still shot on each half of the film before detonation. The actual time of each x-ray flash is recorded on a raster oscilloscope system from the output of a scintillator, blocking oscillator combination.

B7. Explosively Induced Oblique Shocks in Metals.* J. O. ERKMAN, *Stanford Research Institute.*—Detonation of a layer of high explosive in contact with inert matter induces a shock wave in the inert substance. At the interface between detonation product gases and the inert specimen the flows in the gas and in the specimen must be parallel and the pressure must be continuous across the interface. These conditions may be satisfied by a shock or a rarefaction wave in the detonation product gases originating at the intersection of detonation front and explosive-specimen interface. In either case the angle of inclination, β, between detonation front and undisturbed interface has an important influence on the strength and orientation of the induced shock in the specimen. If the reflected wave is a rarefaction and the flow is supersonic in specimen and gases, the problem is solved in detail using the method of characteristics and assuming hydrodynamic behavior in detonation gases and specimen. The shock profile in the specimen and the pressure at any point on the interface will be described for several metals and several angles of incidence.

* Supported in part by Office of Chief of Ordnance, U. S. Army.

B8. Random Occurrence of Meteors in the Upper Atmosphere. T. J. KEARY AND H. J. WIRTH, *U. S. Navy Electronics Laboratory* (introduced by F. N. D. Kurie).—This paper reports an experimental study of the distribution of time intervals between bursts of 43.5 Mc/s signals received over a 690-km path from Stanford, California, to San Diego, with the object of determining whether or not the bursts occurred completely at random. The distribution of time intervals observed is consistent with the distribution expected if the bursts are produced by scattered radiation from the ionized trails of meteors which enter the upper atmosphere at random. The number of time intervals observed less than one second is appreciably less than number calculated. This would be the case if some bursts were not observed when the interval between bursts is comparable to the duration of the bursts. The difference between observed and calculated values for large intervals for which the actual number of observations is small is not statistically significant. The observed number of triplets of equally spaced bursts substantially agrees with the number expected if the bursts occurred at random. The data used in this analysis were the intervals preceding 778 bursts observed during 0400–0600 hr on August 3, 1956, and those preceding 446 bursts observed during 0500–0700 hr on November 6, 1956.

B9. Measurements of Pressure over a Series of Solid Waves in Flowing Water with and without a Mean Flow Shear Generator Placed Upstream. A. MOILLIET, *Pacific Naval Laboratory*, AND R. W. STEWART, *Institute of Oceanography, University of British Columbia* (introduced by W. N. English).—A Plexiglas surface consisting of 25–2 in. waves ($\lambda = 10h$) was installed in the upper wall of the working section of the PNL low turbulence water tunnel. The 3rd, 6th, 15th, and 24th waves were each provided with 11 equidistant pressure measuring points. A rack of 80 manometer tubes was photographed at several velocities to record the pressure distribution at a given instant. The experiment was repeated with the addition of a grid 5λ upstream from the 1st wave which served as a mean flow shear generator. Photographs of results will be shown and discussed with relation to results obtained by Stanton* and Motzfeld.*

* Batchellor and Davies, *Surveys in Mechanics* (Cambridge University Press), p. 229.

B10. Lloyd Mirror Effects in Undersea Sound Fluctuation. C. D. MAUNSELL, *Pacific Naval Laboratory.*—With an extremely smooth sea surface a well defined Lloyd mirror interference pattern may be observed in the sound field from an undersea source. More usually the surface cannot be considered as a plane mirror or even as a stationary one. There are large random phase shifts in signals received by a surface reflection. The interference between these reflected signals and those received by a direct path through the water produces fluctuation in the sound level at a receiver. For random changes in effective path length of several wavelengths it can be assumed that all phase differences between 0 and 2π are equally probable. The amount of fluctuation to be expected for an arbitrary ratio of signal strength between direct and reflected components has been calculated. For signals recorded on a logarithmic scale a maximum standard deviation of 7.9 db is predicted in the case of equality of direct and reflected components. Measurements made with sound pulses using carrier frequencies of 1.5, 8, and 18 kc will be compared with the theoretical prediction. Some deficiencies in this model of only two interfering components will be discussed.

B11. Color Images from Black and White Negatives by the Method of Reconstructed Wavefronts.* ALBERT V. BAEZ† AND EDWARD FISHER, *University of Redlands.*—Gabor has

shown that it is possible to conduct the process of image formation in two distinct steps. The first is the production of a hologram or Fresnel diffraction picture in which recognizable object details may vanish. The second is the reconstruction of the object by diffraction of a wavefront at the hologram. The effective focal length of the hologram is strongly wavelength dependent. This can be used to create a colored reconstruction from a black and white negative. If different parts of the object were illuminated by different colors, these same colors will, in principle, appear in the reconstruction. A white source, illuminating a black and white hologram reconstructs the colors of the object. Since Gabor has already shown that depth (z) information from different planes of a thick transparent object can be extracted from a single hologram, it remains to state that colors, associated with different wavelengths (λ) can also be stored in the hologram. Thus, we can extract either (x,y,z) or (x,y,λ) information from a single hologram.

* This work was supported by the Office of Naval Research.
† On leave at Stanford University.

THURSDAY MORNING AT 9:30

ROOM 101

(E. T. JAYNES presiding)

Solid-State Physics, I

C1. Activation Energy for the Surface Migration of Tungsten. P. C. BETTLER, *Linfield Research Institute*.—An experimental measure of an activation energy Q involved in the surface diffusion of tungsten on tungsten has been evolved from studies of the effect of high electric fields on the change in tip shape of sharpened tungsten needles. The heated needle (1600°K to 2200°K) is operated in dc electric field in a standard field emission microscope tube. The high electric field causes certain of the low-index crystal planes to enlarge or "build-up." The rate and extent of build-up can be determined by observing the time rate of change of the field emission pattern and the field emission current for constant applied potential. By comparing the times t_1 and t_2, at temperatures T_1 and T_2 respectively, required for a given degree of build-up, Q can be found from the formula

$$\frac{t_1}{t_2}=\frac{T_1 e^{Q/RT_1}}{T_2 e^{Q/RT_2}},$$

where R is the universal gas constant. A value for Q of 60 000 cal/mole has been obtained.

C2. Initial Stages of Oxidation of Germanium. J. R. LIGENZA, *Bell Telephone Laboratories, Murray Hill, New Jersey* (introduced by M. M. Atalla).—The initial stages of oxidation of carbon monoxide reduced Ge powder has been studied with a vacuum microbalance sensitive to 1/300 of a GeO_2 layer at an oxygen pressure of 75 mm Hg and at temperatures from 25° to 400°C. The oxidation laws change with temperature and the extent of oxidation. The initial oxygen uptake is consistent with the viewpoint that the CO reduced surfaces are atomically clean. The first oxygen layer forms nearly instantaneously on the cleaned surface. At temperatures below 250°C the second layer forms according to the logarithmic rate law in agreement with the results of Green and Kafalas. Subsequent oxidation is not logarithmic but obeys a Mott and Cabrera thin-film type equation. At temperatures above 250°C the second layer forms in less than one minute. Oxidation rates are slow throughout the temperature range measured. Even at 400°C only 5 layers of GeO_2 formed in 3 hours. Activation energies for the logarithmic law and for the Mott and Cabrera equation were calculated.

C3. Possible Water along Dislocations.* R. N. TUCKER AND P. GIBBS, *University of Utah*.—A tentative explanation for pulses in electrical conductivity of heated wet corundum[1] will be discussed: Water is held in the bulk along dislocation lines, which act as "storage pipes." The desorption process leaves behind conduction carriers. Sometimes the ends of the "storage pipes" are plugged with other impurities. As the specimen is heated, pulses are observed in the conduction current each time a dislocation is "drained" of water. This desorption process is initiated when the impurity plug acquires sufficient thermal energy to escape, and the water is thereupon released to slide out with an activation energy of about 16 kcal/mole. It appears that the number of pulses is proportional to the number of dislocations, and that they can also be triggered by mechanical stress, as suggested by the "sliding mechanism."[2]

* Supported by the Office of Naval Research.
[1] Tucker and Gibbs, Bull. Am. Phys. Soc. Ser. II, 2, 300 (1957).
[2] P. Gibbs, Tech. Rept. III, University of Utah, Salt Lake City (July 10, 1957).

C4. Dielectric Loss in Corundum.* F. M. WANLASS, R. N. TUCKER, AND P. GIBBS, *University of Utah*.—A 0.10-in. diam single crystal rod of Linde corundum was bent in a 1-cm arc containing the c axis. This added $\sim 2\times 10^7$ "oriented" dislocations/cm^3 to the $\sim 10^8$ "random" dislocations already present/cm^3. Electrical contact was made through coatings of "Platinum Bright." Dielectric loss was measured with the electric field parallel to the bend axis, and transverse to it, successively, as a function of frequency and temperature. In preliminary runs, a peak in Q^{-1} corresponding to ~8.0 kcal/mole was greatly enhanced with the parallel field. A "high temperature absorption edge" ($Q^{-1}>0.1$) was found with an activation energy ≈55 kcal/mole. At 100 kc, the edge appears to shift from 1150°C with parallel field to 690°C with transverse field.

* Supported by the Office of Naval Research.

C5. Fracture of Germanium.* R. S. COLLIER, H. H. MCINTOSH, AND P. GIBBS, *University of Utah*.—A search has been made for evidence for a dislocation origin for fracture in high purity germanium. The time delay between the application of stress and the onset of plastic flow or brittle fracture is measured as a function of purity, stress, and temperature (between liquid nitrogen and the melting). Earliest tests suggest that an activation energy is involved in both cases. Photomicrographs compare the dislocation structure (as revealed by etching the surface) before and after fracture.

* This research was supported in whole or in part by the United States Air Force, monitored by Aeronautical Research Laboratory, Wright Air Development Center.

C6. "Clean" Germanium Surfaces.* H. H. McINTOSH, R. N. TUCKER, AND P. GIBBS, *University of Utah.*—Conduction current across the widths of single crystal bars (1×2×8.5 mm) of 30 ohm-cm Eagle-Picher germanium was recorded while the bars were broken in two by the slow application of three-point loading. Contacts were arranged such that the two broken pieces remained in parallel after fracture, and there were no electrical effects except those resulting from deformation and the introduction of two "really clean" surfaces. Preliminary tests gave the following rough results: Fracture in air at liquid nitrogen temperature produced a current pulse of about 0.60 μa max and 10-msec duration. Fracture at room temperature in various ambient atmospheres gave a (somewhat linear) decrease in current, followed by a stationary value. Initial current was 0.12 ma, and the incremental decreases and times required were about: air, 1.82 μa, 20 msec; argon, 1.60 μa, 15 msec; oxygen, 0.30 μa, 10 msec; nitrogen, 0.20 μa, 5 msec; water-saturated nitrogen, 1.90 μa, 20 msec.

* This research was supported in whole or in part by the United States Air Force under Contract No. AF33(616)-5016, monitored by Aeronautical Research Laboratory, Wright Air Development Center.

C7. A Model of Heterogeneous Slip Mechanism in Metals.* N. E. FRIEDMANN AND D. ROSENTHAL, *University of California, Los Angeles.*—Heterogeneous grain deformation, easy and difficult slip, orientation dependence of lattice strains have led to a revision of Taylor's homogeneous five slip mechanism in plastically-deformed polycrystalline metals as follows. The deformation is assumed to start as a single slip in the grain interior and revert to multislip near the boundary in the fraction mV of the grain volume, V. If deformation bands are disregarded, a linear variation of the rotation vector can be assumed in each grain. The displacement vector in mV is then the solution of LaPlace's equation with conditions of single slip on the inner boundary and uniaxial tension on the outer boundary. Because of the intractable form of the problem the strains in the interior are estimated from the known values on the boundaries. Following Bishop's analysis[1] a monotonic variation with m is found for σ/t (applied/resolved shear stress ratio) in almost every orientation. Large orientation dependence of lattice strains are thus explainable by variation of m as well as variation of resolved shear stress-strain relationships.

* Supported by U. S. Air Force, ARDC, AF18(600)-1022.
[1] J. F. W. Bishop, Phil. Mag. **44**, 51 (1953).

C8. X-Ray Evidence of Heterogeneous Plastic Deformation in Metals.* D. ROSENTHAL AND W. B. GRUPEN, *University of California, Los Angeles.*—Lattice strains in a polycrystalline aluminum alloy were determined under uniaxial compression from shifts of various x-ray diffraction peaks. In the plastic range the results indicated: (a) easy and difficult slip, (b) less strain hardening in the surface grains than in the bulk of metal, and (c) large variation of strain hardening with x-ray orientation. These and other reported discrepancies with Taylor's homogeneous five slip mechanism of plastic deformation have led to a modified, heterogeneous, model of slip described in a companion paper.[1] In this model the variation of strain hardening with position and orientation is shown to be consistent with the behavior of single crystals. Also, resolved shear stress-strain relationships for various grain aggregates can be derived from lattice strain data with the help of the model. These relationships are found to be within the limits of scatter obtained for single crystals.

* Supported by U. S. Air Force, ARDC, AF18(600)-1022.
[1] N. E. Friedmann and D. Rosenthal, Bull. Am. Phys. Soc. Ser. II, **2**, 372 (1957).

C9. A Comparison of $\pi-\pi$ to $\pi-\sigma$ Electron Forces between Molecules. W. W. ROBERTSON AND S. E. BABB, JR., *University of Texas.*—The absorption spectrum of benzene in dilute solution in a nonpolar solvent shifts to the red with increasing hydrostatic pressure of the solution.[1] The shift is the result of increasing dispersive interaction between chromophore and solvent with increasing density of solution and has been more or less satisfactorily interpreted on the basis of the London dispersion formula. Haugh and Hirschfelder[2] have pointed out, however, that the dispersion energy is more specifically stated in terms of the interaction between $\sigma-\sigma$ electrons, $\sigma-\pi$ electrons and $\pi-\pi$ electrons of the interacting molecules. Their calculations show that $E_{\sigma\sigma}>E_{\sigma\pi}>E_{\pi\pi}$ for the lower polyenes. The present work has attempted to test this result experimentally by observing spectral shifts with pressure for suitably chosen chromophores and solvents, e.g., benzene in benzene and in n-pentane, etc. Little difference has been found between $\pi-\pi$ and $\pi-\sigma$ bond interactions as far as spectral shifts are concerned, the small difference existing indicating that $E_{\pi\pi}>E_{\sigma\pi}$.

[1] Robertson, Babb, and Matsen, J. Chem. Phys. **26**, 367 (1957).
[2] E. F. Haugh and J. O. Hirschfelder, J. Chem. Phys. **23**, 1778 (1955).

C10. Absorption Coefficients of Methyl, Ethyl, n-Propyl, and n-Butyl Alcohol.* M. OGAWA AND G. R. COOK, *University of Southern California* (introduced by G. L. Weissler).—Optical absorption coefficients of methyl, ethyl, n-propyl, and n-butyl alcohol have been studied in the vacuum ultraviolet region between 1300 A to 500 A, and the intensities of about 25 light source emission lines were measured by the photoelectric method. The data for the 4 vapors show strong, broad absorption continua with a maximum between 700 A to 800 A, together with weak local variations superimposed over the continuous background. The continuous absorption of methyl, ethyl, n-propyl, and n-butyl alcohol is 800 cm^{-1}, 1460 cm^{-1}, 2020 cm^{-1}, and 2390 cm^{-1} at 1085 A and increases to a maximum of 1600 cm^{-1}, 2770 cm^{-1}, 4060 cm^{-1}, and 5000 cm^{-1}, respectively; from the maximum the absorption decreases to 1310 cm^{-1}, 2250 cm^{-1}, 2830 cm^{-1}, and 3280 cm^{-1} at 555 A. The absorption coefficients at the maximum are proportional to the numbers 2.9, 5.0, 7.3, and 9.0, respectively. Although these numbers are rather close to the number of hydrogen-carbon bands, the detailed mechanism for the continuous absorption has not as yet been ascertained.

* This work has been in part supported by the Geophysical Research Directorate of the Air Force Cambridge Research Center and by the Office of Naval Research.

C11. Absorption Coefficients of Benzene and Hydrogen.* S. M. BUNCH, G. R. COOK, M. OGAWA, AND A. W. EHLER,† *University of Southern California.*—The optical absorption coefficients of benzene have been studied in the vacuum ultraviolet between 1340 A and 430 A using 50 light source emission lines. The continuous absorption, over which is superimposed some localized band absorption, is attributed to photoionization and begins at the first ionization limit of 9.24 ev with a coefficient of 600 cm^{-1}. It rises to a first maximum of 2100 cm^{-1} at 930 A, and from 835 A increases further to a second, broad maximum of 4300 cm^{-1} at 710 A, followed by a gradual decrease to 1400 cm^{-1} at 477 A. This may be compared to the much lower absorption of H_2 which has been remeasured with photoelectric techniques and agrees well with earlier photometric results.[1]

* This work in part supported by the Geophysical Directorate of the Air Force Cambridge Research Center and by the Office of Naval Research.
† Now at Douglas Aircraft Company, Santa Monica, California.
[1] Po Lee and G. L. Weissler, Astrophys. J. **115**, 570 (1952).

C12. Optical and Paramagnetic Spectra in Irradiated Alcohols. L. A. WEBB AND R. S. ALGER, *U. S. Naval Radiological Defense Laboratory.*—Simple alcohols, bombarded at liquid

nitrogen temperature with ionizing radiations, become colored and exhibit an electron paramagnetic resonance hyperfine structure (EPR HFS) characteristic of the particular alcohol.[1] Optical absorption measurements have been extended from the visible to 2200 A and the color centers were bleached both thermally and optically. Irradiated ethanol and methanol show an increased absorption near the characteristic uv bands. Although the visible color centers can be removed without disturbing the EPR HFS, optical bleaching in the uv markedly changes the HFS and reduces the uv absorption. In general the side bands in the HFS bleach much faster than the central peak and in some cases new bands are formed. Methanol changes from a triplet to a doublet while ethanol, isobutanol and *n*-butanol follow the general rule. Thermal bleaching products no analogous changes in the HFS. In methanol all spins bleach uniformly between −134 and −130°C while the visible color centers disappeared in both ethanol and methanol at −160°C. At −196°C both color centers and spins are stable, e.g., irradiated samples have been stored up to eight months under liquid nitrogen without appreciable loss of color centers or spins.

[1] T. H. Anderson and R. S. Alger, Bull. Am. Phy. Soc. Ser. II, 1, 379 (1956).

C13. Absorption Bands of Thallium Resulting from Collisions with Rare Gases.* SHANG YI CH'EN AND THOMAS H. WARNOCK, *University of Oregon* (introduced by R. T. Ellickson).—The diffuse bands of thallium which appeared due to the presence of rare gases were studied by means of a Bausch and Lomb large Littrow spectrograph. Both red and violet bands were observed near the sharp series line λ3776, and the diffuse series lines λ2768 and λ2380. Associated with the λ3776 and the λ2380 lines, violet bands were displayed only for the light gases He, Ne, and Ar, and red bands only for the heavy gases Kr and Xe. Broad violet bands with much greater separations between the band maxima and the line than those for the above mentioned two lines, were found near the λ2768 line for all gases used, while red bands appeared only for Kr and Xe. The band separations for the red bands are around 24 and 45 cm^{-1} for Kr and Xe, respectively, near all the aforementioned 3 lines, while those for the violet bands are much larger and differ considerably for the different lines. The data were compared with the corresponding observations with the alkali atoms,[1] and the emission bands of thallium at the neighborhood of the sharp series line 5350.[2]

* Supported by the National Science Foundation.

[1] Ch'en, Bennett, and Jefimenko, J. Opt. Soc. Am., **46**, 182 (1956); S. Y. Ch'en and O. Jefimenko, J. Chem. Phys. **26**, 256 (1957); O. Jefimenko and S. Y. Ch'en, J. Chem. Phys. **26**, 913 (1957).

[2] H. Krefft and R. Rompe, Z. Physik, **73**, 681 (1932).

C14. Temperature Dependence of Young's Modulus in Refractory Oxides. C. E. DIXON AND L. L. BIENVENUE, *Atomics International.*—The temperature dependence of the Young's modulus of polycrystalline BeO, MgO, and Al_2O_3 has been measured to their grain boundary relaxation temperatures by the Forster method. In this method the resonant frequency of a specimen about $4.0\times\frac{1}{4}\times\frac{1}{16}$ in. is measured by suspending it at its ends by fine wires from a crystal driver and a crystal pickup. The resonant frequencies were near 1000 cps. In addition to the modulus data some internal friction information was obtained. In all of the materials, the Young's modulus decreased linearly with increasing temperature until the onset of grain boundary stress relaxation where a rapid decrease occurred coincident with a sharp rise of internal friction. In the linear region the temperature coefficients were 0.8×10^{-4}/°C, 1.8×10^{-4}/°C, and 1.2×10^{-4}/°C for BeO, MgO, and Al_2O_3 respectively. The relaxation temperatures for BeO, MgO, and Al_2O_3 were 1400, 1250, and 1250°C, respectively. The grain boundary stress relaxation reduced Young's modulus by about 15%.

C15. Anisotropic Effects in the Thermal Lattice Expansion of Alumina and Beryllia. D. J. KLEIN, *Atomics International.*—The thermal expansions of the lattice constants of Al_2O_3 and of BeO have been measured from room temperature to 1600°C with particular emphasis on the change of c/a. The diffraction furnace and the method of reduction of the data will be described. Results indicate that the difference between the thermal expansions in the two directions is in each case small compared with the thermal expansion itself. Since the thermal expansion coefficient is itself small, little strain is set up in such material on heating and cooling. Negative results of experiments carried out in an attempt to observe residual strains by observation of line shapes confirm the above conclusions. This isotropy of thermal expansion is considered to be a factor contributing to the well-known good behavior of these materials at high temperatures.

THURSDAY AFTERNOON AT 2:00

DINKELSPIEL

(K. K. DARROW presiding)

Invited Papers on Nuclear Structure

D1. Relation of Nuclear Size to Saturation and Nuclear Compressibility. K. A. BRUECKNER, *Indiana University.* (30 min.)

D2. Qualitative Aspects of Nuclear Saturation. K. M. WATSON, *University of California, Berkeley.* (30 min.)

D3. Nuclear Sizes and the Weizsäcker Semi-Empirical Formula. A. E. S. GREEN, *Florida State University.* (30 min.)

D4. Attempt at Correlation of Different Information on Nuclear Sizes. H. A. BETHE, *Cornell University.* (45 min.)

THURSDAY AFTERNOON AT 1:30

Room 101

(M. CHODOROW presiding)

Electron Physics

E1. Study of Plasma Magnetron.* H. W. BANDEL, R. M. HILL, AND J. E. DRUMMOND,† *Microwave Physics Laboratory, Sylvania Electric Products, Inc.*—An experimental probe study of smooth anode magnetrons with and without filling gas revealed axial symmetry in both phase and amplitude of the internally generated microwave signal. This is in disagreement with the existing theory of vacuum and plasma magnetrons. Rough ion density measurements on the plasma magnetron and the observed oscillation frequencies near multiples of the electron cyclotron frequency are in substantial agreement with the dispersion law of Gross. A sharp change in the ion density at the maximum radius of primary electrons was indicated by studies of ion bombardment effects along the magnetic axis. These findings were incorporated as postulates for a new theory of plasma magnetron operation. This theory predicts radial nodes of rf charge and current densities, as well as properties of the rf electric field configurations in the various modes of operation.

* This work was performed under Signal Corps Contract.
† Now employed at Poulter Laboratories, Stanford Research Institute.

E2. Field Emission: Electrical Stability and Life of the Cold Cathode.* E. E. MARTIN, J. K. TROLAN, AND W. P. DYKE, *Linfield Research Institute.*—Electrons are emitted by cold tungsten needles in vacuum under the action of an intense electric field. The smooth, clean field emitter is shown to be electrically stable. Instability is caused by the contamination and roughening of the emission surface by incident foreign material. Stability is maintained by use of: (a) dense envelope material which is resistant to the diffusion of atmospheric gases; (b) very high vacuum and clean, refractory electrode surfaces; (c) an anode geometry which encloses and isolates the discharge and whose clean surface adsorbs most gases entering the enclosure. Conditions are described under which cold tungsten cathodes give stable steady state emission for periods up to 3000 hrs at average power levels of one watt; life termination is avoided. At this power level, current drift rates observed during fixed voltage operation, i.e., about 5% per 100 hrs, are in agreement with predicted values based upon postulated changes of the effective emitting area at a rate proportional to emitted current. These methods make available to practical applications the advantages of a cold cathode.

* This work was supported by the U. S. Air Force.

E3. Electron Beam Apparatus for Density Measurement in Rarefied Gas Streams.* F. C. HURLBUT, *University of California, Berkeley.*—Values of the density in a rarefied gas stream remain unavailable to conventional experimental technique where conditions of the local flow field make infeasible one of the appropriate measurements, as in the boundary layer very near to the surface, or where the equation of state is itself in question, as in a reaction mixture. A direct measure of gas density may, however, be provided by the attenuation of an electron beam directed across the region under study. An apparatus for this purpose is described and the results of preliminary tests in the University of California rarefied gas wind tunnel are discussed. The solution of an Abel-type integral equation permits the calculation of a point density function for the flow field from electron beam attenuation data in the axisymmetric case.

* Work supported by the Office of Naval Research and by the U. S. Air Force, Wright Air Development Center.

E4. Hall Effect in Gaseous Conductors. J. R. WOODYARD AND BYRON EDWARDS, *University of California, Berkeley.*—An ionized gas can be made to have many of the properties of a solid-state semiconductor.[1] For example, the Hall effect and the magnetoresistive effect can be made much greater than in solid semiconductors. Measurements of Hall effect and magnetoresistive effect were made in static fields up to 3000 gauss for neon, hydrogen, mercury vapor, and other gases. Either an external source of ionization or self ionization maintained by the applied current was used. A Hall coefficient R_h, of 30 volt cm/amp gauss was measured for neon at 500 μ with a $1/p^3$ variation with pressure. The effect is nonlinear in B at higher flux densities. The Hall effect in a gas has been used as a temperature-insensitive magnetic flux density meter. The Hall effect in an ionized gas (without an external dc magnetic field) has also been used as a microwave wattmeter where it has the advantage of much greater sensitivity than that provided by solid semiconductors which have been used experimentally in Hall-effect wattmeters.[2]

[1] P. H. Miller, Bull. Am. Phys. Soc. Ser. II, 1, No. 3, 120 (1956).
[2] H. E. M. Barlow, Proc. Inst. Elec. Engrs., Part C 104, 35–42 (1957).

E5. Glow Amplifier.* C. W. HARTMAN, S. L. MERCER, AND D. H. SLOAN, *University of California, Berkeley.*—Gaseous electron multiplication in crossed electric E and magnetic B fields gives equal lateral velocity $V=E/B$ for all electrons resulting from collisions in gas. Ions "pump" into cathode in 10^{-7} sec, neutralize, return, and serve again as atomic dyodes. This pump opposed sputtering and allows low pressure elsewhere. Ions from over-heated anode vapors bombard cathode, and eject electrons which cannot cross the 1000 gauss to the ions' source; hence there is no transition into an arc in air at 10^{-3} mm. Ten kv dc anode heat limited the 7 cm² beam to 7 amp. Multipactor electrons, further multiplied in gas, gave more than 50 kw cw output at 159 mcps with 8 kv 12 amp input to a cold-cathode glow magnetron. A cathode of material giving half as many bombardment electrons could have the deficiency made up by injected control electrons.

* This work was supported in part by the U. S. Air Force.

E6. High-Frequency Breakdown in Oxygen. ELSA HUBER SOLT, ARNOLD G. KRAMER, AND R. J. MUNICK, *Hughes Research Laboratories.*—Breakdown electric fields *vs* gas pressure have been measured in oxygen for various electrode separations and at two widely different frequencies. One set of measurements were made with parallel-plate electrodes at 9.8 mcps, the other set were performed at 9000 mcps in a microwave resonant cavity. Data for the two frequencies will be compared and related to the theoretical breakdown curve. An interesting anomaly in the experimental curve appears at high pd which cannot be explained in terms of the usual high-frequency breakdown theory.

E7. Microwave Properties of a Hot Magneto-Plasma. J. E. DRUMMOND, *Stanford Research Institute.*—A Boltzmann transport analysis shows that transconductance arises in an ionized gas in a magnetic field at very high temperatures. For microwaves in such a plasma, the currents at a given point can be determined by electric fields opposite in phase to the fields existing at the given point. Thus the behavior of very-high-temperature plasmas can be markedly different from that of

low-temperature plasmas in regard to transmission and absorption of high-frequency radio waves. This has led to the prediction of power transfer resonances at frequencies somewhat shifted from integral multiples of the electron-cyclotron frequency and to regions of abnormal transmission. This provides a microwave transmission measurement of both electron density and temperature for very dense and very hot plasmas.

E8. Nonresonant Microwave Spectra and the Investigation of Reorientation Collision Cross Sections. GEORGE BIRNBAUM, *Hughes Aircraft Company*, AND A. A. MARYOTT, *National Bureau of Standards*.—Classically speaking, symmetric top molecules have a nonrotating component of the dipole moment parallel to the total angular momentum vector which can absorb energy from an electromagnetic field because of the effect of collisions. The resulting nonresonant or relaxation spectrum which lies in the microwave region has been studied[1] and as discussed here yields collision cross sections in disagreement with Anderson's quantum theory of pressure broadening.[2] These cross sections are larger than the kinetic values and smaller than those derived from experimental values of microwave rotational lines. It is shown that the functional dependence of cross section on the pertinent molecular constants can be explained in terms of a semiclassical theory as due to the large molecular reorientation arising from the torque between two colliding dipoles. The dependence of cross section on temperature predicted by this theory has been verified by further experiments.

[1] G. Birnbaum, J. Chem. Phys. **27**, 360 (1957).
[2] P. W. Anderson, Phys. Rev. **76**, 647 (1949).

E9. Electrodynamic Containment of Charged Particles. HAYWOOD SHELTON AND RALPH F. WUERKER, *The Ramo-Wooldridge Corporation*, AND ROBERT V. LANGMUIR, *California Institute of Technology*.—Charged particles of iron 0.5 to 10 microns diameter have been maintained in dynamic equilibrium in vacuum against gravitational and interparticle forces by the technique of strong focusing. An axially symmetric potential distribution $V=(\alpha/2)(r^2-2z^2)\sin\Omega t$ is produced by applying an alternating voltage between a ring and end caps. Microscopic observation shows the motion of a single particle to be a figure-eight Lissajous pattern with characteristic frequencies of motion $\omega_r=0.707\alpha q(m\Omega)^{-1}$ and $\omega_z=1.414\alpha q(m\Omega)^{-1}$ upon which is superimposed the driving frequency Ω. The charge to mass ratio (q/m) has been measured and checked by three methods; displacement by a superimposed dc electric field, beating the resultant particle motion against a superimposed sinusoidial signal, and determining the lower frequency region of stability as predicted from Mathieu function theory. When more than one particle is suspended in a sufficiently strong confining field, a stable array can be formed in which each particle vibrates about a point of static equilibrium. Static arrays of up to and more than ten particles have been observed. If the strength of dynamic containment is decreased by varying Ω or α the particles escape from their local potential traps and behave as a confined gas. The ordered array is again reinstated by increasing the confining force. Both positive and negative particles have been simultaneously confined.

E10. Theory of Electrodynamic Suspension System. H. C. CORBEN, *The Ramo-Wooldridge Corporation*.—The theory of the suspension system described in the previous abstract is developed for an arbitrary number of particles with arbitrary charges and masses suspended against the influence of gravity and their mutual electrostatic repulsion. If the amplitude of oscillation about equilibrium for each particle is small compared with the interparticle separation and if the applied frequency is large compared with the Lissajous frequency, an approximate solution of the equations of motion yields a set of algebraic equations relating the equilibrium positions of the particles to their masses and charges and to the amplitude V_0 and angular frequency Ω of the applied voltage and the dimensions Z of the chamber. Special configurations for a small number of particles are examined in detail. For a large number of identical particles the average interparticle separation must exceed the critical length $(m\Omega^2Z^4V_0^{-2})^{\frac{1}{3}}$ independent of their charge, so that the maximum possible mass density of particles suspended in this manner is less than $(E/Z\Omega)^2$, where E is the rms applied field, averaged over the chamber.

E11. Transition of Glow Discharges to Transient Power Arcs for Various Low-Pressure Gases and Varied Cathodes.* RUSSELL G. WESTBERG, *University of California, Berkeley* (introduced by L. B. Loeb).—Analyses of glow-to-arc transitions with fast oscilloscope have been continued. This paper presents data on glow-to-arc transitions with Al cathodes in oxygen at 50 to 470 microns, and in nitrogen, at 174 and 280 microns, in a 140 centimeter long tube. Cathode current increases from milliamperes up to several amperes within 10^{-8} second have been found. For oxygen, the velocity of propagation of the initial light front in the tube has been found to increase suddenly from a velocity of about 1×10^9 cm/sec for pressures below 128 microns, to $4-8\times10^9$ cm/sec at pressures from 184 microns up. Instantaneous spatial distributions of potentials within the tubes have been plotted for times during the transitions. Studies of nonthermal transitions with tungsten cathodes and nitrogen, 280 microns to 2.5 mm Hg also show sudden transition to arcs at high velocities of propagation of the initial light front within the tube. Copper, nickel, and platinum cathodes in helium show extremely rapid increases in cathode current indicating probable transitions, although with use, the copper and platinum cathodes tend to "clean up," so that arcing ceases.

* This work was supported by funds from the Research Corporation and the Office of Naval Research.

E12. "Kinetic" Ejection of Electrons from Tungsten by Lithium and Cesium Ions.* PAUL M. WATERS, *University of California, Berkeley*.—Measurements have been made of the secondary emission coefficient γ_i of an atomically clean tungsten surface bombarded by cesium and lithium ions. Ion energies range from 250 to 1500 ev. The total yield for these two cases is compared with the "non-Auger" yield of He^+ on molybdenum extrapolated by Hagstrum.[1] In addition, the energy distribution of the secondary electrons of 1000-ev lithium ions is compared with the extrapolated distribution of Hagstrum for 1000-ev helium ions. Behavior of yields as a function of surface contamination will also be discussed.

* This work has been supported by the Office of Naval Research.
[1] H. D. Hagstrum, Phys. Rev. **104**, 672 (1956).

E13. Direct Observation of the Spread of Geiger Counter Pulses Along the Anode in Air.* GEORGE A. CONDAS, *University of California, Berkeley* (introduced by Leonard B. Loeb).—Using an oxidized Ni mesh cathode, coaxial geometry, triggering the counter at one end by ionization of single axially transverse α-particle tracts, initiating the oscilloscope sweep by electrical signal, a recording photomultiplier scanning of the counter with mm wide slit at different distances from the α track, progress of the pulses is observed. The intense ionization of the triggering event gives pulses of about 10^{-7} sec duration which choke by space charge in agreement with Amin's[1] observations on point corona. As potential increases near threshold, the pulses advance further along the wire, showing surprisingly large jitter and extending to the length of the tube only at and above threshold. Velocity

measurements yield values of about 10^4 cm/sec, varying slowly with voltage and pressure from 50 to 200 mm Hg. These are one-tenth those reported by Huber[3] using electrical pulse rise times and assuming all pulses to traverse the whole wire.

* This work was supported by funds from the Office of Naval Research.
[1] M. R. Amin, J. Appl. Phys. 25, 210 (1954).
[3] E. L. Huber, Phys. Rev. 97, 267 (1955).

E14. Observation of Phenomena Inside the Vapor Cylinder Formed During Explosion of a Metallic Wire.* WILLIAM M. CONN, *Kansas City.*—An exploding wire goes through several stages prior to the final explosion, including formation of a liquid cylinder which becomes unstable and forms unduloids. A column of metallic vapor is formed showing the "characteristic pattern" consisting alternately of striations and sections of smaller diameter. We showed[1] by means of deposits on glass slides, etc., that the vapor cylinder is hollow. Striations occur at least up to 72 μf and 11 kv. Phenomena occurring inside of the vapor cylinder have been investigated by means of "windows," such as a tube of Mylar closed by a Mylar window (0.007 in. thick) at the end nearest the wire; an open box made from Mylar; Plexiglas; or a strip of Mylar $\frac{1}{4}$ in. wide for a wire 2 in. long. Thin Mylar windows were found to remain intact during the first stages of the explosion including deposit on the slide which takes place within 2–10 μsec. The windows are placed before triggering the explosion at the desired level of the vapor column, for example, immediately adjacent the wire.

* Partially supported by AFCRC contract with Temple University, Philadelphia, Pennsylvania.
[1] W. M. Conn, Z. angew. Phys. 7, 539 (1955).

E15. Electron Gun Employing a Tungsten Point Field Emission Cathode.* J. D. SLEETH AND E. G. BROCK, *Linfield Research Institute.*—As part of a program to adapt the field emission cathode to a microwave oscillator, an electron gun consisting of a stainless steel apertured anode cup and a tungsten point field emission cathode[1] has been assembled and tested. The diameter of the apertures used in the assemblies was 0.0197 in. Spacings between the inner anode surface and the tip of the tungsten point ranged from 0.001 in. to 0.005 in. The alignment technique used to center the tip of the tungsten point in the aperture to a tolerance of 0.0003 in. and the method of holding the parts of the gun in position after assembly are described. Testing of the assemblies has revealed that essentially 100% beam transmission through the aperture can be achieved. As a direct result of the small aperture and close spacings the voltage required for emission has been decreased by a factor of 10 or more.

* Supported by the U. S. Army Signal Corps.
[1] A similar structure has been constructed and tested by J. E. Taylor and E. G. Brock at the General Electric Research Laboratory.

E16. Latest Developments in Dispenser Cathodes. LEO J. CRONIN, *Semicon Associates, Inc.*—This paper classifies the various types of dispenser cathodes now available to tube designers. These types include, but are not limited to, the so-called nickel, tungsten, thoria, and thorium dispensers. The main discussion will concern latest developments with the Philips Dispenser Cathode. A brief description is given of the latest form of the Philips Dispenser Cathode. The emission characteristics are discussed along with evaporation, activation, and life. New developments point the way to lowered evaporation rates even at high emission densities. Instances are cited where the cathode has delivered over 10 A/cm^2 steady dc emission. Recent advanced designs, assembly techniques, and applications are covered.

E17. Dissociation Limit of O_3^-.* P. L. RANDOLPH AND R. GEBALLE, *University of Washington.*—The dissociation limit of O_3^- has been measured in a mass spectrometer. The spectrometer uses a source that produces "monoenergetic" electrons by the RPD method.[1] The electron energy scale is calibrated with retarding potential measurements on the electron energy distribution. Ion kinetic energy measurements are made by use of a retarding potential within the ion formation chamber. A calibration of the ion kinetic energy scale is made by use of SF_6^-.[2] The appearance potential for O^- ions from dissociative attachment has been measured for several values of ion energy. These were extrapolated to zero kinetic energy. The dissociation limit thus obtained is $3.5_{-0.2}^{+0.3}$ volts above the ground state of O_2. Using 5.1 volts for the dissociation energy of O_2, an electron affinity of $1.6_{-0.2}^{+0.3}$ volts is obtained for O^-. This agrees, within our experimental error, with the result of photodetachment measurements by Branscomb, Smith, and Burch[3] who found 1.465 volts. It is anticipated that instrumental refinements now being incorporated will permit a substantial increase in accuracy.

* Supported in part by the Office of Ordnance Research of the U. S. Army.
[1] Fox, Hickam, Grove, and Kjeldaas, Rev. Sci. Instr. 26, 1101 (1955).
[2] W. M. Hickam and R. E. Fox, J. Chem. Phys. 25, 642 (1956).
[3] Branscomb, Smith, and Burch, Paper presented at ASTM E-14 Committee on Mass Spectrometry Meeting, May 20–24, 1957, New York.

FRIDAY MORNING AT 9:30

Room 100

(D. R. YENNIE presiding)

Invited Papers on Field Theory and Experiments

F1. Recent Experimental Work on the Electron Magnetic Moment. PETER FRANKEN, *University of Michigan.* (30 min.)

F2. Quantum Electrodynamics at Small Distances. S. D. DRELL, *Stanford University.* (30 min.)

F3. Electromagnetic Structure of the Nucleon in Local Field Theory. ROBERT KARPLUS, *University of California, Berkeley.* (30 min.)

F4. Interaction between Nucleons and Anti-Nucleons. GEOFFREY F. CHEW, *University of California, Berkeley.* (30 min.)

FRIDAY MORNING AT 9:30

Room 370

(W. E. MEYERHOF presiding)

Low-Energy Nuclear Physics I

G1. Annihilation of Positrons in Organic Compounds.* CHARLES R. HATCHER, LOUIS BROWN, AND W. E. MILLETT, *University of Texas.*—Using a standard delayed coincidence technique the percent of the positrons which decay with a long mean life and these annihilation rates ($\tau_2 \sim 10^{-9}$ sec) have been measured for annihilation in twenty-two organic compounds. Most of the molecules studied consist of benzene rings with one or two radicals attached to the ring which tend either to lower or increase the electron density on the ring. The halogen family, fluorobenzene, chlorobenzene, bromobenzene, and iodobenzene showed the widest variation of percent τ_2 having $(24\pm2)\%$, $(14\pm2)\%$, $(6\pm2)\%$, and $(4\pm2)\%$, respectively. The value of τ_2 on the other hand changed only slightly. An empirical relationship has been used to set up an upper limit on the percent τ_2 in those substances for which no long component was observed. Assuming that the τ_2 component is due to positronium formation, a rough correlation can be found between the charge distribution in the molecule and the percent τ_2.

* Supported in part by the U. S. Air Force Office of Scientific Research of the Air Research and Development Command.

G2. Photoprotons from C^{12}.* W. R. DODGE AND W. C. BARBER, *Stanford University.*—Proton energy and angular distributions from the electro- and photodisintegration of C^{12} have been measured with an 18-inch, 120° double-focusing magnetic spectrometer. Nine KI scintillation crystals mounted on the focal plane of the spectrometer provide simultaneous measurement of nine proton momentum groups. Preliminary measurements taken with a primary energy of 30 Mev indicate a proton angular distribution peaked at nearly 90° slightly skewed in the forward direction for both electro- and photodisintegration and a sharp peak in the energy spectrum corresponding to photon absorption at the giant resonance with transitions to the ground state of B^{11}. There is also evidence for other proton levels. The results of more recent measurements will be described.

* Supported by the joint program of the Office of Naval Research, the U. S. Atomic Energy Commission, and the Air Force Office of Scientific Research.

G3. Resonant Absorption of Gamma Rays.* S. S. HANNA AND LUISE MEYER-SCHÜTZMEISTER, *Argonne National Laboratory.*—In the radiative capture of particles having a fixed energy and direction of motion, the energy of the radiation varies with the angle of emission but is discrete at a given angle. These features have been used in observing the resonant nuclear absorption by direct measurement of the transmission through an absorbing sample. The source of radiation was the reaction $C^{13}(p,\gamma)N^{14}$ at the resonant energy $E_p=1.75$ Mev corresponding to the level in N^{14} at $E_{ex}=9.18$ Mev. The 9.18-Mev radiation was detected at an angle θ through a slit of angular width $\Delta\theta$, with a NaI counter and a 10-channel analyzer. The inverse absorption $N^{14}+\gamma-N^{14*}$ was obtained by interposing between the source and the slit a quantity of liquid nitrogen, 27 cm thick, contained in two Dewar flasks. The energy of the emitted radiation was then varied by changing the angle of observation, and the nuclear absorption was observed at an angle of 81.° At this angle the Doppler shift produced by the forward motion of the radiating nucleus just compensates for the energies of recoil in the emission and in the absorption. From measurements with several different slit widths we obtain a total width $\Gamma=0.35\pm0.1$ kev and a partial width $(2I+1)L_\gamma=61\pm6$ ev for the level in N^{14}.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

G4. Photofission Cross Sections of Several Heavy Nuclei.* KENNETH M. CLARKE AND JOHN R. HUIZENGA, *Argonne National Laboratory.*—The photofission cross sections near threshold of Th^{232}, U^{233}, U^{234}, U^{235}, U^{236}, U^{238}, and Np^{237} have been measured using an ionization chamber. Protons accelerated to 1.380 and 3.645 Mev by the Argonne Van de Graaff accelerator impinged on a thick CaF_2 target. Gamma rays of 6.14, 6.91, and 7.11 Mev produced by the $F^{19}(p,\alpha\gamma)O^{16}$ reaction were used to excite the heavy nuclei. Employing the known thick target intensity ratio[1] $[I_{6.14}/(I_{6.91}+I_{7.11})]$ plus the measured gamma flux and the fission counting yield at each of the two above proton energies, the (γ,f) cross sections at 6.14 and 7.0 Mev were calculated. The heavy-element samples were essentially uniform oxide deposits of about 1 mg/cm² on platinum. The cross sections for Th^{232}, U^{236}, U^{238}, and Np^{237} are all at least a factor of two greater at 6 Mev than at 7 Mev. While the cross sections for U^{233} and U^{234} are increasing in this energy interval, that for U^{235} is essentially constant.

* Based on work performed under the auspices of the U. S. Atomic Energy Commission.
[1] Bent, Bonner, and Sippel, Phys. Rev. **98**, 1237 (1955).

G5. Gamma-Ray Yield from the Proton Bombardment of Silicon.* NORMAN K. GREEN, RICHARD F. WISEMAN, AND EDMUND A. MILNE, *U. S. Naval Postgraduate School.*—Natural silicon and electromagnetically separated silicon-29 (80% Si^{29}) were bombarded with protons of energies between 1000 and 1900 kev. Gamma rays were observed with a 2-in. ×2-in. well-type NaI(Tl) crystal placed around the target. Targets were prepared by vacuum coating the silicon on tantalum sheet. In addition to those resonances previously reported[1,2] resonances were observed at proton energies of 1476, 1482, 1500, 1727, and 1748 kev. The resonances at 1500, 1727, as well as the previously reported[2] resonance at 1648 are attributed to Si^{29}. These investigations are being continued.

* This work was supported in part by the Office of Naval Research.
[1] Seagondollar, Woods, De Souza, and Glass, Bull. Am. Phys. Soc. Ser. II, 2, 304 (1957).
[2] S. P. Tsytko and Iu. P. Antuf'ev, J. Exptl. Theoret. Phys. U.S.S.R. **30**, 1171 (1956) [Soviet Phys. Jetp **3**, 993 (1957)].

G6. Radiative Capture of Protons in Ne^{20}.* R. E. PIXLEY, R. E. HESTER, AND W. A. S. LAMB, *University of California Radiation Laboratory, Livermore.*—The cross section for the reaction $Ne^{20}(p,\gamma)Na^{21}$ has been obtained at 400 kev. The thin target yield obtained by counting the positrons of Na^{21} is $Y=2.2\pm0.7\times10^{-14}$ β^+/incident proton. The activity was identified by observing the half-life. The corresponding cross section is $2.7\pm1\times10^{-8}$ barn. The targets were prepared by bombarding aluminum with 50-kev neon ions. These targets were analyzed by elastic scattering of protons.

* This work was done under the auspices of the U. S. Atomic Energy Commission.

G7. Electron Disintegration of Elements from $Z=3$ to $Z=79$.* H. W. KENDALL AND U. MEYER-BERKHOUT, *Stanford University.*—Yields of protons and deuterons from electron disintegration of a series of elements from Li^6 to Ta^{181} have been studied. Targets were bombarded with 500-Mev electrons and disintegration fragments of momentum $p \leq 550$ Mev/c, after momentum analysis with a 36-in. magnetic spectrometer, were detected in plastic or NaI(Tl) scintillation counters. Angular distributions of protons and deuterons in the range of laboratory angles from 40° to 135° were determined absolutely by comparison with known elastic electron-scattering cross sections. Proton and deuteron yields are proportional to Z, and the ratio of deuteron to proton differential cross sections (taken either at equal particle energy or equal momentum) appears to be approximately constant with a value in the range 0.07−0.12. The results are interpreted in terms of a transverse electron-nucleus interaction, which is effectively a high-energy photodisintegration process. This process gives rise to high-energy protons and neutrons originating in the nuclear volume. The large deuteron yields are consistent with a pickup reaction at the nuclear surface in analogy with high-energy (p,d) and (n,d) reactions. No detailed theory explains the high deuteron yields, which are also observed in other processes.

* Supported by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission, and by the Office of Scientific Research Air Research and Development Command.

G8. Neutron Spectra from Mock Fission Sources. E. TOCHILIN, *U. S. Naval Radiological Defense Laboratory.*—Commercial mock fission sources containing Po as the alpha emitter and a mixture of B, Be, F, and Li are now available as calibration standards for fission type spectra. Theoretical calculations by W. N. Hess show fairly good agreement with primary fission neutrons.[1] The neutron spectrum from one such source has been measured with nuclear track plates over an energy range from 0.4 to 7.3 Mev. The spectrum obtained was considerably lower in energy than from fission neutrons. On the basis of these data and experimental (α,n) spectra presented by Hess for B, Be, BF_3, and Li sources, calculations are made for a new mixture to better approximate the primary fission neutron spectrum. Experimental data on the effect of hydrogen as a moderator of fission neutrons are also presented.

[1] W. N. Hess, "Neutrons from (α,n) Sources," UCRL 3839 (July, 1957).

G9. Mass-Yield Distributions in Particle-Induced Fission of Radium.* R. C. JENSEN AND A. W. FAIRHALL, *University of Washington* (introduced by Boris A. Jacobsohn).—Radiochemical measurements of the mass distributions of fission fragments from fission induced in Ra^{226} by 11-Mev protons, 22-Mev deuterons, and 22- and 44-Mev helium ions reveal an unusual behavior. For proton-induced fission the mass-yield curve shows three peaks of comparable magnitude, corresponding to separate symmetric and asymmetric fission modes. The curve for deuteron-induced fission shows predominantly symmetric fission. The curves for helium-ion induced fission look more "normal": for 22-Mev helium ions asymmetric fission predominates, with a peak-to-valley ratio of about 2. For 44-Mev helium ions the mass-yield curve is flat between mass numbers 90 and 140. The cross sections for fission are in every case lower by factors of from about 3 (44-Mev helium ions) to 50 (11-Mev protons) than corresponding fission cross sections in thorium. Analysis of these data indicates that asymmetric fission is dying out more rapidly with decreasing Z^2/A than symmetric fission for nuclides in the region of radium.

* Supported in part by the U. S. Atomic Energy Commission.

G10. Mass Division in Fission.* A. W. FAIRHALL AND R. C. JENSEN, *University of Washington* (introduced by Boris A. Jacobsohn).—The observation of a narrow mass distribution in the symmetric fission mode of bismuth[1] and radium[2] target nuclei makes it attractive to attribute the filling in of the symmetric valley of the mass distribution curves of elements heavier than radium to this fission mode. Over seventy mass-yield curves have been examined on this basis to obtain excitation functions for symmetric fission. The results show that the probability of symmetric fission is a strongly increasing function of excitation energy, and for elements heavier than thorium is not very sensitive to Z or A of the initial compounds nucleus. The conclusion from these data is that symmetric fission occurs promptly in competition with neutron emission up to energies at least as great as 40 Mev, where $\Gamma_f^{(a)}/\Gamma_n$ is of the order of 1 for elements heavier than thorium. The behavior of the asymmetric mode indicates that at least for target nuclei from thorium to neptunium asymmetric fission takes place only at relatively low excitation energies, $\Gamma_f(A)/\Gamma_n$ going to zero below 20 Mev excitation energy.

* Supported in part by the U. S. Atomic Energy Commission.
[1] A. W. Fairhall, Phys. Rev. 102, 1335 (1956).
[2] R. C. Jensen and A. W. Fairhall (to be published).

G11. Inelastic Scattering of 14.5-Mev Neutrons.* D. B. NICODEMUS, *Oregon State College,* J. H. COON, R. W. DAVIS, AND H. E. FELTHAUSER, *Los Alamos Scientific Laboratory.*—When 14.5-Mev neutrons bombard a complex nucleus, some of the inelastically emitted neutrons lose a small fraction of the initial energy and thereby excite only the low-lying levels. Qualitatively such inelastic processes are interpretable in terms of the direct interaction hypothesis. The present report presents new experimental results in the form of differential cross sections for the inelastic neutrons of energy greater than about 9 Mev, the energy band between 9 and 14 Mev being lumped together without detailed energy spectrum information. The angle range studied was from 40° to 150°. A ring scattering geometry was employed with an uncollimated recoil proton scintillation detector used as a crude neutron spectrometer. Within the 30% accuracy of the measurements, the cross sections for Pb, Sn, and Cu decrease monotonically as the angle increases from 40° to 150° as follows: Pb, 22 to 4 mg/sterad; Sn, 20 to 5 mb/sterad; Cu, 10 to 5 mg/sterad. The curves become progressively flatter with decrease in atomic weight. A curve for Fe shows a broad minimum with values of 5 mg/sterad near 90° and values of 10 mb/sterad at 40° and at 150°.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

G12. Double Moderator Neutron Detector.* J. DE PANGHER, *Hanford Laboratories Operation, General Electric Company.*—A fast-neutron detector consisting of a BF^3 counter inside a cylinder of paraffin plus an outer removable shell of paraffin is being investigated which measures flux density, dose, and average neutron energy. The core, with wall thickness 2¾ inches and height 12 inches, is a fluxmeter while the total assembly is a dosimeter.[1] Two experimental facts which help in measuring average neutron energy accurately below 1.2 Mev and approximately between 1.2 and 5 Mev are (1) the slowly varying response of the fluxmeter, and (2) the accurate linearity of the ratio $r=$(dosimeter counts/fluxmeter counts) with neutron energy E, below 1.2 Mev and approximate linearity between 1.2 and 5 Mev. For complex spectra, we measure $R=$(dosimeter counts/fluxmeter counts) and evaluate the average energy $\bar{E}=E(r\cong R)$.

* This paper describes in part, work conducted under contract between the General Electric Company and the U. S. Atomic Energy Commission.
[1] J. De Pangher and W. C. Roesch, Phys. Rev. 100, 1793 (A) (1955).

FRIDAY MORNING AT 10:00

Room 101

(W. K. H. PANOFSKY presiding)

High-Energy Nuclear Physics

H1. K-Meson Photoproduction from Hydrogen at 120° c.m. and 1040-Mev Photon Energy.* T. C. TERMAN, V. Z. PETERSON, AND C. E. ROOS, *California Institute of Technology.*—A nuclear emulsion stack placed at 45±1° and 14 in. from a 3-in. diameter liquid hydrogen target was used to detect stopping K^+ mesons produced in the hydrogen by 1100-Mev bremsstrahlung. The reaction assumed is $\gamma+P\rightarrow\Lambda^0+K^+$. Scanning is for $\pi^\pm$ mesons, and K mesons, with careful examination of all proton endings for secondaries. Efficiency for detecting minimum secondaries is measured using electrons from $\mu-e$ decay, and averages 86%. The ratio of protons to pions to K's ending is 700:280:1. To date 6 K's have been detected in 1.6 cc of emulsion. All events have light secondaries, as do 7 events from carbon found previously.[1] The 6 hydrogen events correspond to a photoproduction cross section of 2×10^{-31} cm²-sterad^{-1} for K's emitted at 120° (center-of-mass) and a mean photon energy of 1040 Mev. Additional experiments with direct exposures, and using a pulsed-magnet spectrometer are in progress.

* This work was supported in part by the U. S. Atomic Energy Commission.
[1] Peterson, Roos, and Terman, Bull. Am. Phys. Soc. Ser. II, 235 (1957).

H2. Evidence for the Production of a Neutral Pion in an Antiproton Annihilation Event.* ALICE H. ARMSTRONG AND GLENN M. FRYE, JR., *Los Alamos Scientific Laboratory.*—An antiproton of 110 Mev annihilates in flight producing a star in nuclear emulsion with 3 charged mesons and 4 heavier prongs. An electron-positron pair is found 76 μ from the vertex and closely aligned with it. The pair is best explained as resulting from a γ ray from the decay of a π^0 meson which was formed in the annihilation. The most likely interpretation of the event is that the antiproton annihilated with a proton in N^{14} or O^{16} with the production of two positive pions, a neutral pion, and a negative pion, all of which escaped the nucleus; and a negative pion which was absorbed. The pion energies, including $m_\pi c^2$, are as follows: π^+, 214±2; $\pi^\pm$, 635±138; $\pi^\pm$, 628±131; π^0, $188<E_{\pi^0}<404$; π^-, $286<E_{\pi^-}<484$ Mev.

* Work performed under the auspices of the U. S. Atomic Energy Commission.

H3. Polarization of Muons in K^+-Meson Decay.* CHARLES A. COOMBES, BRUCE CORK, WILLIAM GALBRAITH, GLEN R. LAMBERTSON, AND WILLIAM A. WENZEL, *University of California Radiation Laboratory, Berkeley.*—Positive particles emitted from a tantalum target at 90° to the internal beam of the Bevatron were momentum-analyzed and focused by a set of quadrupoles onto a detector system composed of scintillation and Čerenkov counters. K^+ mesons of momentum 500 Mev/c were identified by velocity and range. Muons from stopped K^+ mesons which decayed vertically downward via the $K_{\mu3}$ mode were detected with another set of counters and were identified by range. Decay positrons from those muons which stopped in an aluminum "precessor" were detected by counters placed above and below. A magnetic field of 25 gauss could be applied to the "precessor" to effect a time dependence of the up-down asymmetry of the $\mu-e$ decay. The experiment gives $a_0=-0.31\pm0.04$ for positrons of range greater than 9 g/cm² of aluminum. Here a_0 is defined by the equation $N(\theta)d\Omega=N(\pi/2)(1+a_0\cos\theta)d\Omega$, where $N(\theta)$ is the number of decay positrons observed in solid angle $d\Omega$ at an angle θ relative to the initial direction of motion of the muon. The observed asymmetry, which is a measure of the polarization of the muon,[1] therefore has the same magnitude and sense as that observed in the $\pi^+-\mu^+-e^+$ chain,[2-4] and shows that parity is not conserved in the decay of the K^+ meson. The result is strong evidence that the spin of the K^+ meson is zero.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
[1] T. D. Lee and C. N. Yang, Phys. Rev. **104**, 254 (1956); also **105**, 1671 (1957).
[2] Garwin, Lederman, and Weinrich, Phys. Rev. **105**, 1414 (1957).
[3] J. I. Friedman and V. L. Telegdi, Phys. Rev. **105**, 1681 (1957).
[4] Cassels, O'Keefe, Rigby, Wetherell, and Wormald, Proc. Phys. Soc. (London) **A70**, 543 (1957).

H4. Multiplicity of Pions in Nuclear Interactions in Carbon Produced by Primaries of Energies in the Region of 10 to 100 Bev.* LUISA F. HANSEN, *University of California, Berkeley.*—Measurements of ionization in the region of the relativistic rise, together with momentum measurements, make it possible to identify pions, protons, and electrons with momentum up to 20 Bev/c. The method is applied to the analysis of secondaries produced in carbon by cosmic radiation at sea level. The primaries have an energy above 10^{12} ev and the secondaries are detected in a cloud chamber. In a sample of 30 showers analyzed to date, in almost every case a complete analysis of the shower could be made. Further results will be reported.

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.

H5. Latitude Variation of 27-Day Cosmic-Ray Intensity Decreases.* ROBERT R. BROWN, *University of California, Berkeley.*—The latitude variation of cosmic-ray intensity decreases has been calculated using the geocentric modulation mechanism proposed by Parker.[1] In comparing the result of this calculation with neutron monitor observations of the February, 1956, intensity decrease, the parameter $C(\infty)$ in the geocentric model was chosen so as to give a high-latitude variation comparable to that observed[2] at Climax, Colorado. Thus, the intensity variations are expected to range from 1% to 10% in going north from the geomagnetic equator to latitudes near the "knee" of the latitude curve. Experimental data obtained from cosmic-ray monitors at low-geomagnetic latitudes display intensity variations larger than given by this calculation. In particular, variations observed[3] at Mt. Norikura, Japan (30°N geomagnetic latitude) are approximately twice as large as expected; also, ion chamber data[4] from Huancayo, Peru, suggest that neutron variations at this location are at least twice as large as given by the geocentric modulation model. Possible interpretations of these results will be discussed.

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
[1] E. N. Parker, Phys. Rev. **103**, 1518 (1956).
[2] Meyer, Parker, and Simpson, Phys. Rev. **104**, 768 (1956).
[3] M. Wada (private communication).
[4] S. E. Forbush (private communication).

H6. High-Energy Neutron Cross Sections.* PAUL H. BARRETT, *University of California, Santa Barbara.*—A high-energy beam of neutrons was produced by 6.2-Bev protons from the Bevatron striking a polyethylene target. The absorption cross section for neutrons in this beam has been measured for Pb, Al, Cu, and nuclear emulsion. The neutrons are detected by nuclear emulsions using the density of stars and star size as the basis of the analysis. Cross sections obtained

will be compared with other measurements of cross section for high-energy neutrons and protons.

* Supported by the U. S. Air Force Office of Scientific Research and the U. S. Atomic Energy Commission.

H7. Gas Bubble Chamber Characteristics.* B. HAHN AND G. RIEPE, *University of Fribourg, Switzerland.*—An experimental gas bubble chamber,[1] 4 cm in diameter and 5 cm deep, has been investigated on its performance in the electron beam of a 32-Mev betatron. For various gas-liquid systems the pressure variations inside the chamber during the expansion has been measured and gas bubble chamber characteristics as, e.g., sensitive time, bubble density, and rate of bubble growth have been studied. Optimum operation conditions will be discussed.

* This research has been sponsored in part by the Air Research and Development Command, U. S. Air Force, through the European Office, ARDC.

[1] B. Hahn, Nuovo cimento **4**, 944 (1956); B. Hahn and J. Fischer, Rev. Sci. Instr. **28**, 656 (1957).

H8. Nonlinear Coupled Resonances in A. G. Accelerators.* G. PARZEN,† *Midwestern Universities Research Association.*—The coupled nonlinear resonances $2\nu_y+\nu_x=N$ and $2\nu_y-\nu_x=0$ in the betatron oscillations of the strong focusing A.G. accelerator have been investigated for a general class of magnetic fields. It is believed that the method used can be easily extended to treat any magnetic field. The method used reduces the problem to an eigenvalue problem. This eigenvalue problem differs from the usual eigenvalue problem met in quantum mechanics in that the eigenvalue is given by two parameters (E, E') instead of just one parameter, E. The location and the stability limits of the nonlinear resonances become equivalent to finding the gaps in the allowed eigenvalues of the system. The gaps in the eigenvalues are found by a generalization of the weak binding approximation in solid state theory. The results of the method for the $2\nu_y+\nu_x=N$ and $2\nu_y-\nu_x=0$ resonances will be given for a general class of magnetic fields.

* Supported by the U. S. Atomic Energy Commission.
† On leave from the University of Notre Dame.

H9. Evidence for Excited-Nucleon Model of Pion Production in $n-p$ Collisions at Bevatron Energies.* FRED N. HOLMQUIST, WILLIAM B. FOWLER, AND WILSON M. POWELL, *University of California Radiation Laboratory, Berkeley.*—An analysis of 522 multiprong events observed in a $n-p$ Bevatron experiment using a hydrogen-filled diffusion cloud chamber shows good evidence for the existence of the $(\frac{3}{2}, \frac{3}{2})$ isobaric nucleon in events of charge configuration $n+p\rightarrow p+n+\pi^++\pi^-$. The large range of energetically possible Q values permits a broad investigation of this isobar as well as of possible higher energy isobars. If in the above reaction both nucleons are excited to the $(\frac{3}{2}, \frac{3}{2})$ isobaric state, with subsequent decay via pion emission, then theory shows the proton and π^+ are associated 21 times out of 22. The $Q(p,\pi^+)$ and $Q(n,\pi^-)$ distributions are then phenomenologically related to the interaction cross section observed in pion-nucleon elastic scattering. Approximately one-half the events have been analyzed, and of these about one-quarter are identified as examples of $n+p\rightarrow p+n+\pi^++\pi^-$. Q-value distributions have been plotted as weighted histograms in order to include the measurement errors. Both the $Q(p,\pi^+)$ and $Q(n,\pi^-)$ distributions show a characteristic peak at 0.14 Bev, whereas the $Q(p,\pi^-)$ and $Q(n,\pi^+)$ distributions do not. When $Q(p,\pi^+)$ and $Q(n,\pi^-)$ distributions are added together, the statistics are doubled and experimental-bias effects are reduced. A comparison with the π^+-p scattering cross section shows that at Bevatron energies the two nucleons are often excited to the $(\frac{3}{2}, \frac{3}{2})$ isobaric state and decay without large interference effects.

* This work was done under the auspices of the U. S. Atomic Energy Commission.

FRIDAY AFTERNOON AT 1:30

DINKELSPIEL

(M. LEVY presiding)

Invited Papers on Parity

I1. Recent Theoretical Developments. C. N. YANG, *Institute for Advanced Study, Princeton.* (30 min.)

I2. Experimental Evidence from Beta Decay. M. GOLDHABER, *Brookhaven National Laboratory.* (30 min.)

I3. Experimental Evidence from $\pi-\mu-e$ Decay. L. LEDERMAN, *Columbia University.* (30 min.)

I4. Experimental Evidence from Hyperon Decay, I. L. STEVENSON, *University of California Radiation Laboratory.* (30 min.)

I5. Experimental Evidence from Hyperon Decay, II. M. SCHWARTZ, *Brookhaven National Laboratory.* (30 min.)

FRIDAY AFTERNOON AT 2:00

Room 370

(I. PERLMAN presiding)

Low-Energy Nuclear Physics, II

J1. Initial Step in a High-Energy Nuclear Reaction.* LESTER WINSBERG, *University of California Radiation Laboratory, Berkeley.*—The initial step in a high-energy nuclear reaction is considered to be the collision of an incoming nucleon with an individual nucleon in the nucleus. One possible test of this assumption is to compare the cross sections of

$(p,2p)$, (p,pn), and $(p,2n)$ reactions from the bombardment of nuclei with protons. If the assumption is correct the first two reactions can proceed in one step whereas the latter requires at least two steps and should, therefore, have a much lower cross section. Another test of the assumption can be made by comparing the cross sections of reactions which result in a product nucleus with the same mass number as that of the target. In these cases the minimum number of steps is equal to the change in the atomic number. For the case where the atomic number does not change, e.g., (p,p'), $(p,n\pi^+)$, etc., the reaction can go in one step. Thus, the $(p,p\pi^+)$ and the (p,n) reactions can go in one step whereas the $(p,p2\pi^+)$ and $(p,n\pi^-)$ reactions require at least two steps and should, therefore, proceed with a much lower cross section. These predictions for both types of reaction are borne out by the experimental results which will be reviewed.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

J2. Reactions of 5.7-Bev Protons with Copper Targets. D. W. BARR AND E. K. HYDE, *University of California, Berkeley.*—The formation cross sections of 59 radioactive isotopes from mass number 3 (tritium) to mass number 68 (gallium) have been determined by radiochemical methods. The yield pattern is quite different from that observed with 340-Mev protons corresponding to a marked increase in the probability of large energy transfers to the struck nucleus. The results will be compared with recent Monte Carlo calculations of the high-energy nucleonic cascade performed at Los Alamos by Metropolis, Turkevich, and others. Production and reabsorption of π mesons is probably an important energy transfer mechanism contributing to high yields over a wide range of mass numbers. This work was performed under the auspices of the U. S. Atomic Energy Commission.

J3. Recoil Ion Study of the $B^{11}(d,p)B^{12}$. L. F. CHASE, JR., AND G. IGO, *Stanford University.*—In the study of the angular distributions in stripping reactions, the outgoing proton or neutron is ordinarily detected. The presence of contaminants in the target material sometimes makes these measurements difficult. A method, which involves the detection of recoil ions instead of stripped particles and which discriminates against competing reactions, is being used here in a study of the $B^{11}(d,p)B^{12}$ reaction. A 2.8-Mev deuteron beam is passed through a chamber containing pentaborane (B_5H_9) gas or diborane, boron trifluoride, or boron trichloride at a pressure of a few mm Hg. The radioactive B^{12} recoil ion formed in the (d,p) reaction is stopped in the gas. The position of the recoil ion is detected by its subsequent β decay ($E_{max}=13.4$ Mev, $t_{\frac{1}{2}}=0.025$ sec). A counter telescope consisting of three plastic scintillators is used to detect the beta particles. In order to discriminate against background and competing reactions, only beta particles above a fixed energy are counted. The cyclotron beam and the counter telescope are gated on alternately for a time equal to the half-life of B^{12}. The specially-designed scattering chamber and the recoil ion distributions will be described. Anisotropics in the β-particle counting rates at mirror position will be discussed in terms of nuclear alignment. The methods described here can be applied to other nuclear reactions.

J4. On the Interpretation of Resonance Energies Using H_3^+ Beams. R. O. BONDELID, J. W. BUTLER, AND C. A. KENNEDY, *U. S. Naval Research Laboratory.*—Mass-1 and -2 proton beams from the Large NRL Van de Graaff accelerator have been used to observe several (p,γ) reactions using a two-meter electrostatic analyzer as the energy selecting instrument (absolute calibration $\pm 0.05\%$). When choosing the midpoint of the rise from a thick-target yield curve as the energy of the resonance, the mass-2 results are approximately 0.05% lower than the energy predicted from the mass-1 yield curves. The energy at the peak of the resonance as determined by mass-1 and mass-2 observations on thin targets agree to within 0.02%. The targets were sufficiently thin so that the correction to the energy introduced by target thickness does not materially affect the agreement. An observed asymmetrical shape of the mass-2 thick-target yield curve indicates that the mass-2 particles may exist as such for a depth of penetration into the target of approximately 0.5 kev. Because of the increased range per proton, there is an attendant increase in the yield from the (p,γ) reaction at a lower bombarding energy, thereby causing the apparent shift of the midpoint to a lower energy in the thick-target yield curve.

J5. Transmutation of Nitrogen by Protons from 100 kev to 135 kev.* WILLIAM A. S. LAMB AND ROSS E. HESTER, *University of California Radiation Laboratory, Livermore.*—A portion of the excitation curve of the thermonuclear reaction $N^{14}(p,\gamma)O^{15}$ has been measured using protons of 100 to 135 kev. The cross section of this reaction ranges from $8.5\pm3.7\times10^{-12}$ barn at 100 kev to $1.4\pm0.3\times10^{-10}$ barn at 135 kev. The approximate constant S_0 is defined by $S_0=E\sigma\exp 31.281\,Z_pZ_nA^{\frac{1}{2}}E^{-\frac{1}{2}}$, where E is the energy in the center of mass and is measured in kev, σ is in barns, A is the reduced mass of the interacting nuclei and Z_p and Z_n are the nuclear number of protons and nitrogen, respectively. Based upon these measurements, $S_0=2.7\pm0.2$ kev-barn.

* This work was done under the auspices of the U. S. Atomic Energy Commission.

J6. D−D Reaction at Low Energies.* JAMES E. YOUNG, *Los Alamos Scientific Laboratory.*—Recent experiments by Brolley, Putnam, and Rosen[1] have given the angular distributions for the neutron and proton branches of the D−D reaction in the energy interval 6 to 14 Mev. Calculations, now being prepared for machine evaluation, have been made of the differential cross section and polarization of emitted nucleons. The analysis has been carried out within the framework of the theory of surface reactions, as proposed by Thomas.[2] Coulomb contributions to the particle interactions have been included, and, as well, both final and initial state interactions; the latter being treated through the use of a hard sphere potential, the former through an optical model potential, without spin-orbit modification. Preliminary report on the angular distributions for the neutron branch will be made, and some attention given to the arbitrariness inherent in the use of the phenomenological model.

* Work supported under auspices of the U. S. Atomic Energy Commission.

[1] Brolley, Putnam, and Rosen, Phys. Rev. **107**, 820 (1957).
[2] R. Thomas, Phys. Rev. **100**, 25 (1955).

J7. Elastic Scattering of 40-Mev Protons by Deuterons.* JOHN H. WILLIAMS AND MORTON K. BRUSSEL,† *University of Minnesota.*—40-Mev protons, produced by the first two sections of the Minnesota linear accelerator, were scattered by deuterium gas and detected by a NaI crystal. The angular range from 4° to 90° in the laboratory system was investigated by observations of the scattered protons. The recoil deuterons observed from 4° to 18° in the laboratory provided information on the differential scattering cross section for protons recoiling between the corresponding angles of 164° to 117°. The measured differential cross section (statistical accuracy of $\pm3\%$ or better) shows prominent features of: a minimum resulting from interference between Coulomb and nuclear potential scattering at $\theta_{C.M.}\sim10°$; a broad minimum at approximately 132° where the cross section is less than 2 mb/steradian; an increase at larger angles to a value of 20 mb/steradian at 172°.

* Supported in part by the U. S. Atomic Energy Commission.
† Now at Brookhaven National Laboratory.

J8. P–N Asymmetries at 143 Mev.* S. CARPENTER† AND R. WILSON, *Harvard University.*—The asymmetry in the neutrons produced by allowing the Harvard Cyclotron proton beam of 148±5 Mev and 65±3% polarization to fall on targets of C, Al, Cu, and Pb (each about 10 Mev thick) was found at 20°, 30°, 40°, 50°, 60°, and 70° for neutrons of effective energies of 74, 77, 81, 86, and 93 Mev. Values obtained checked well with the little previous data but were not consistent with the polarization expected from a free *p-n* collision. The asymmetry *versus* angle curve was similar for all energies except that lower energies had lower asymmetries and at 70° the lower energies fell off rapidly while the upper ones remained constant. Except for 70° the values of the asymmetry for the effective energy of 74 Mev were about three-fourths of the values for 93 Mev. For 81 Mev the values from 20° to 70° were 0.06, 0.05, 0.09, 0.15, 0.17, and 0.13 (all ±0.02). Results seemed to have little variation with element.

* This work was supported by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
† Now with Atomics International Division of North American Aviation, Inc., Canoga Park, California.

J9. 184-Inch Cyclotron Beam-Extraction System.* W. F. STUBBINS, E. L. KELLY, J. T. VALE, AND K. M. CROWE, *University of California Radiation Laboratory, Berkeley.*—Particles of momentum $p=1830\ Z$ Mev/c (727±10-Mev protons) are extracted from the 184-inch cyclotron by a regenerative deflector and a magnetic lens system consisting of the edge field of the cyclotron and a channel that reverses the field gradient. The regenerator and channel are formed by pieces of iron supported between the pole faces in a configuration that properly modifies the cyclotron's magnetic field. The magnetic field along stable orbits is maintained at the desired value by compensating iron shims. Particle orbits have their radial amplitude increased to about 9 inches by the regenerator, with the regenerator impulse on the last turn adjusted so that all particles are focused to a small spot radially beyond the regenerator where the regenerator field is very small. This terminates the regenerator action for escaping particles, and the focal point serves as the source for the magnetic lens system. A parallel beam approximately 4 inches square emerges from the cyclotron. The proton beam in the experimental physics cave has a pulse duration in excess of 60 microseconds and an average current of 5×10^{-8} ampere, over an area of 1 by 4 inches. (The repetition rate is 64 cycles per second.)

* This work was done under the auspices of the U. S. Atomic Energy Commission.

J10. Differential Cross Sections for $Li^6(d,p)Li^{7*}$ and $C^{13}(d,p)C^{13*}$.* H. E. CONZETT, AND D. G. HOFFMAN, *University of California Radiation Laboratory, Berkeley.*—The angular distributions of protons from the reactions $Li^6(d,p)Li^{7*}$, (4.61-Mev level) and $C^{13}(d,p)C^{13}$ (ground state) have been measured in the region from 15° to 120°, using 24-Mev deuterons. The differential cross sections for the 4.61-Mev level of Li^7 gives a broad peak at 55° and a minimum near 90°. Preliminary calculations on the 4.61-Mev level indicate poor agreement with the Butler stripping theory. The experimental cross section for $C^{13}(d,p)C^{13}$ has a minimum at 38° and a maximum of 44°, with a steady decrease beyond 44° and a sharp rise below 30°. The Butler theory with $l=1$ and $r_0=4.5\times10^{-13}$ cm is in qualitative agreement but the quantitative fit is poor. Further work at angles below 15° and beyond 120° is in progress. These results and the results of comparison with theory will be reported.

* This work was done under the auspices of the U. S. Atomic Energy Commission.

J11. Nuclear Level Spacings. A. G. W. CAMERON, *Atomic Energy of Canada Limited.*—The shell-dependent level spacing formula developed by Newton[1] depends upon the densities of single-particle orbits near the Fermi level in the nucleon gas. The fit to observed level spacings has been improved by the following procedure: to a first approximation the spacings between the single-particle orbits are equal to the second differences between adjacent nuclear masses. These differences have been calculated using a semiempirical atomic mass formula[2] from which Coulomb, Coulomb exchange, and pairing energy terms have been omitted (in order to distinguish between adding new particles to the nucleus and exciting existing particles). Appropriate averages of these "spacings" have been computed which depend on nuclear excitation energy through the dependence of the averaging procedure on nuclear temperature. Eighty-two observed level spacings have been fitted by this procedure with a root mean square error factor of 1.74. The fit shows that level spacings are proportional to $(2J+1)^{-1}$ to a good approximation.

[1] T. D. Newton, Can. J. Phys. 34, 804 (1956).
[2] A. G. W. Cameron, Can. J. Phys. 35, 1021 (1957).

FRIDAY AFTERNOON AT 1:30

Room 101

(G. E. PAKE presiding)

Nuclear and Paramagnetic Resonance

K1. Dynamic Nuclear Polarization of 6 Day Mn^{52}. M. ABRAHAM, C. D. JEFFRIES, R. W. KEDZIE, AND O. S. LEIFSON, *University of California, Berkeley.**—By saturation[1] of microwave paramagnetic resonance lines we have dynamically produced nuclear polarization of 6 day Mn^{52} and detected the polarization from the resulting γ-ray anisotropy. The experiment is similar to that previously reported[2] for Co^{60}. Approximately 5 mc of Mn^{52} and 100 μg of Mn^{55} were grown into a 500-mg single crystal of $La_2Mg_3(NO_3)_{12}$ 0.24 H_2O, which was placed in the microwave cavity of a paramagnetic resonance apparatus operating at 9000 Mc/sec and 1.5°K. Two γ-ray counters recorded the intensity in directions parallel and perpendicular, respectively, to the dc magnetic field as it was varied through the region of the paramagnetic hfs resonance lines. The spectra are complicated by the fact that there are 2 unequivalent ions, each with a fine structure, resulting in a set of 10 superposed hfs lines. The nuclear g factor ratio $g(Mn^{52})/g(Mn^{55})$ is directly measured, yielding $g(Mn^{52})=0.514\pm0.02$, in good agreement with the static polarization experiments.[3]

* Supported in part by the U. S. Atomic Energy Commission.
[1] A. Overhauser, Phys. Rev. 92, 411 (1953); A. Abragam, Phys. Rev. 98, 1729 (1955); C. D. Jeffries, Phys. Rev. 106, 164 (1957).
[2] Abraham, Kedzie, and Jeffries, Phys. Rev. 106, 165 (1957).
[3] Huiskamp, Diddens, Severiens, Miedema, and Steenland, Physica 23, 605 (1957).

K2. New Upper Limit for the Magnetic Moment of Gallium-66.* J. L. WORCESTER, *Occidental College*, W. A. NIERENBERG, R. MARRUS, AND J. C. HUBBS, *University of California Radiation Laboratory, Berkeley.*—The atomic-beam magnetic resonance method has been used to investigate the Zeeman structure of Ga^{66}. Previous measurements[1] have shown the nuclear magnetic moment to be less than 10^{-3} nuclear magnetons, strongly indicating that the nuclear spin is zero. The new measurements, made in the atomic $^2P_{\frac{1}{2}}$ state at fields of 0.35 and 0.7 gauss, show a single symmetric resonance with a full width at half maximum of about 75 kilocycles. If this full width is taken as an upper limit to possible hyperfine-structure interactions, it is found that the magnetic moment of Ga^{66} is less than 4×10^{-5} nm.

* This research has been supported by the U. S. Atomic Energy Commission.
[1] Hubbs, Nierenberg, Shugart, and Worcester, Phys. Rev. **105**, 1928 (1957).

K3. Nuclear Spins of Au^{191}, Au^{193}, and Au^{195}.* W. B. EWBANK, L. L. MARINO, H. A. SHUGART, AND H. B. SILSBEE, *University of California Radiation Laboratory, Berkeley.*—The nuclear spins of three neutron deficient gold isotopes have been measured by the atomic beam, magnetic resonance, flop-in method using radioactive detection.[1] Results are: for 3-hr Au^{191}, $I=\frac{3}{2}$; for 4.8-hr Au^{193}, $I=1$; and for 17.5-hr Au^{195}, $I=\frac{3}{2}$. The isotopes are formed by Ir(α,kn)Au reactions using 45-Mev alpha particles from the Berkeley 60-in. cyclotron. The iridium target is placed in the atomic beam oven and heated to produce an atomic beam of gold. Atoms passing through the apparatus are collected on a sulfur-coated surface and detected by counting the k x-rays resulting from electron capture. The isotopes responsible for resonance signals are identified by their half-lives. Preliminary hyperfine structure measurements show that Au^{191} and Au^{193} have magnetic moments within 10% of the Au^{197} moment. The hyperfine structure separation of Au^{193} is only 400 ± 200 Mc/sec. Work is continuing on these and other gold isotopes and more accurate moment and hyperfine structure separation measurements will be published later.

* This research is supported jointly by the U. S. Atomic Energy Commission and the Office of Naval Research.
[1] Hobson, Hubbs, Nierenberg, Silsbee, and Sunderland, Phys. Rev. **104**, 101 (1956).

K4. Nuclear Spin of Bi^{206}.* L. L. MARINO, W. B. EWBANK, W. A. NIERENBERG, H. A. SHUGART, AND H. B. SILSBEE, *University of California Radiation Laboratory, Berkeley.*—The nuclear spin of 6.4 day Bi^{206} has been measured by the atomic beam, magnetic resonance, flop-in technique.[1] The value $I=6$ was measured by observing the $F=15/2$, $m_F=-11/2\leftrightarrow-13/2$, and $F=13/2$, $m_F=-9/2\leftrightarrow-11/2$ transitions at several settings of the C field. The isotope was prepared by the Pb(d,2n)Bi reaction with 24-Mev deuterons from the Berkeley 60-in. cyclotron. Chemical separation of the bismuth activity from the target material was accomplished using the method of internal electrolysis. The bismuth atoms passing through the apparatus were collected on a sulfur-coated surface and the activity detected by counting k x-rays following electron capture.

* This research was supported jointly by the U. S. Atomic Energy Commission and the Office of Naval Research.
[1] Hobson, Hubbs, Nierenberg, Silsbee, and Sunderland, Phys. Rev. **104**, 101 (1956).

K5. The Nuclear Moments of Bromine-82. THOMAS M. GREEN, HUGH L. GARVIN, EDGAR LIPWORTH, AND WILLIAM A. NIERENBERG, *University of California Radiation Laboratory, Berkeley.*—The method of atomic beams has been employed to measure the nuclear magnetic moment and the electric quadrupole moment of radioactive bromine-82 by observation of the two transitions $(F=13/2,\ m_F=-9/2)\rightarrow(F=13/2,\ m_F=-11/2)$ and $(F=9/2, m_F=-7/2)\rightarrow(F=9/2, m_F=-9/2)$. The spin of bromine-82 has previously been reported as 5.[1] Measurements have been made at three different values of of magnetic field. The magnetic and quadrupole interaction constants in the zero-field Hamiltonian $H=haI\cdot J+hbQ$ have been determined. The results are, to date: $|a|=205\pm15$ Mc $|b|=874\pm100$ Mc. The uncertainties quoted are several times the experimental uncertainty. The ratio b/a is negative, implying that the two moments have the same sign, but the sign of the magnetic moment has not yet been determined. Values of μ and Q have been computed by the method of Davis *et al.*,[2] and from the results of King and Jaccarino for Br^{79} and Br^{81}.[3] For Br^{82} we find $|\mu|=1.6\pm0.1$ nuclear magnetons and $|Q|=0.7\pm0.1\times10^{-24}$ cm^2. This work was done under the auspices of the U. S. Atomic Energy Commission.

[1] Garvin, Green, and Lipworth, Bull. Am. Phys. Soc. Ser II **2**, No. 6 (1957).
[2] Davis, Feld, Zabel, and Zacharias, Phys. Rev. **76**, 1076 (1949).
[3] J. G. King and V. Jaccarino, Phys. Rev. **94**, 1610 (1954).

K6. Spin of Iodine-124.* HUGH L. GARVIN, THOMAS M. GREEN, AND EDGAR LIPWORTH, *University of California Radiation Laboratory, Berkeley.*—The nuclear spin of 4.5-day iodine-124 has been measured by the atomic-beam flop-in method and found to be 2. The I^{124} was produced by the bombardment of antimony metal in the Berkeley 60-in. cyclotron according to the reactions $Sb^{121}(\alpha,n)I^{124}$ and $Sb^{123}(\alpha,3n)I^{124}$. Because a sizable amount of the 13-hr iodine-123 is also produced during the bombardment, the target material is allowed to decay for approximately 60 hr before processing. This has the effect of reducing the apparatus background and facilitates the identification of I^{124} resonances. After chemical separation from the antimony, the active iodine was mixed with natural-iodine carrier and an rf-discharge tube was used to produce the atomic beam. Resonances were detected by allowing the beam to fall upon silver-coated buttons which were subsequently counted. Identification of the isotope was made from its half-life.

* This work was done under the auspices of the U. S. Atomic Energy Commission.

K7. Spin Echo Measurements on He^3 at Low Temperatures. R. L. GARWIN AND H. A. REICH, *IBM Watson Laboratory.*—Relaxation times and self-diffusion coefficients have been measured in gaseous, liquid, and solid He^3 as a function of temperature and pressure. These experiments are a continuation of our previous measurement[1] using a spin-echo method.[2] Thus far pressures to 70 atmos and temperatures to 1.2°K have been investigated, but the pressure range will be extended to 140 atmos to observe the solid phase transition reported by Mills and Grilly.[3] Measurements on dilute solutions of He^3 in He^4 should give information on the He^3-roton interaction in the superfluid.

[1] Garwin, Kan, and Reich, Proc. NSF Conf. Low Temp., Baton Rouge, La., (1955).
[2] E. L. Hahn, Phys. Rev. **80**, 580 (1950).
[3] R. L. Mills and E. R. Grilly, Proc. Fifth Intern. Conf. Low Temp., Madison, Wisconsin, (1957).

K8. Deuteron Magnetic Resonance in KD_2PO_4.* JOHN L. BJORKSTAM AND EDWIN A. UEHLING, *University of Washington.*—This resonance has been observed above and below the ferroelectric Curie temperature. The line width is about 2 kc and the thermal relaxation time is several minutes at room temperature. Comparison with the proton relaxation time of about 1 sec[1] in KH_2PO_4 leads to the inference that the correlation time for the random motion of deuterons is considerably longer than for the protons. From observation of the quadrupole splitting and its dependence on orientation, the quadrupole coupling constant is found to be 119 ± 1 kc and the asymmetry parameter 0.131. The major axis of the electric field gradient tensor is along the bond direction within the experimental error of measurement. The difference between

the coupling constant above and below the Curie temperature is small, indicating that the structure of the hydrogen bond is almost unaffected by the transition. This is consistent with the results of infrared data.[3] The dependence of thermal relaxation on crystal orientation will be discussed.

* We are indebted to Werner Känzig of the General Electric Company and Hans Jaffe of the Clevite Research Center for the loan of crystals used in these studies.
[1] Roger Newman, J. Chem. Phys. **18**, 669 (1950).
[2] G. S. Landsberg and F. S. Baryshanskaya, Compt. rend. acad. sci. U. S. S. R. **61**, 1027 (1948); K. Brugger, Diplomarbeit, Swiss Federal Institute of Technology, Zürich, 1951.

K9. Concentration Dependence of Chemical Shifts and T_1's for Protons in Aqueous Solutions of Acetic Anhydride.* M. EISNER, *Texas A. & M. College.*—T_1 and chemical shifts have been measured, at 5000 gauss, for protons in both OH and CH_3 groups in aqueous solutions of acetic anhydride. No shift is observed between the OH and CH_3 until acetic acid proportions are reached; the subsequent shifts are in substantial agreement with those reported by Bhar and Linstrom.[1] Both T_1's exhibit minima, however, they display different dependence on the macroscopic viscosity. An analysis of the T_1 variations, in the region of the anomalous behavior of the chemical shifts, seems to lend support to the explanation of this anomaly in terms of the effect of an active solvent on the dimer-monomer equilibrium.

* Supported in part by the U. S. Air Force Office of Scientific Research of the Air Research and Development Command.
[1] Bhar and Lindstrom, J. Chem. Phys. **23**, 1958 (1955).

K10. Double Resonance Detection of $K^{39,41}$ Quadrupole Interactions in $KClO_3$.* D. KAPLAN AND E. L. HAHN, *University of California, Berkeley.*—The pure Cl^{35} quadrupole spin echo in $KClO_3$ is excited at 28 mc by application of two successive rf pulses at times $t=0$ and $t=\tau$. The Cl echo amplitude is observed while a separate third rf pulse is applied at $t=\tau$ to excite the K spins in the same sample. Preliminary measurements at pulse carrier frequencies of 529 kc for K^{39} and 646 kc for K^{41} (at 25°C) show that the Cl echo amplitude decreases, indicating that the K spins suddenly reorient as a result of quadrupole resonance. The K^{39}/K^{41} quadrupole moment ratio $=1.22$ in agreement with a previous measurement.[1] The change in local K−Cl magnetic dipolar interaction destroys the precessional coherence necessary for Cl echo formation. This is most efficient for $\theta \approx n\pi$ in a single crystal, where θ is the pulse mutation angle for the K spins, and n is an odd integer not too large. The resonances can be observed in single crystals and powder.

* Supported by the Office of Naval Research and the National Security Agency.
[1] Lee, Fabricand, Carlson, and Ravi, Phys. Rev. **91**, 1395 (1953); $\omega_{K41}/\omega_{K39}=1.220\pm0.002$.

K11. Pure Quadrupole Resonance of Gamma Irradiated Hexamethylenetetramine.* P. A. CASABELLA, A. H. SILVER,† AND P. J. BRAY, *Brown University.*—The N^{14} pure quadrupole resonance in $(CH_2)_6N_4$[1] has been studied as a function of Co^{60} gamma-ray irradiation using a Pound-Watkins type recording spectrometer. The resonances were observed to decrease in integrated intensity with the increasing dosage exponentially such that $\ln(N/N_0)=-0.017R$. In this expression N represents the integrated intensity of the resonance which is proportional to the number of nuclei contributing to the resonance, N_0 is the intensity of the resonance in the unirradiated sample, and R is the radiation dosage in megaroentgens. It is believed that the primary effect of irradiation is to ionize a $(CH_2)_6N_4$ molecule thus changing the coupling constant of the nitrogen atoms in that molecule and in several of its neighbors. Using this model an equation for the intensity as a function of dosage has been derived, which, for small dosages reduces to $\ln(N/N_0)=-(1+x)\alpha R$. Here x represents the number of molecules whose quadrupole coupling constants are changed appreciably by an ionized molecule, and α is the fraction of molecules ionized per unit dosage of radiation.

* Research supported by the U. S. Atomic Energy Commission.
† Present address: Scientific Laboratory, Ford Motor Company, Dearborn, Michigan.
[1] G. D. Watkins and R. V. Pound, Phys. Rev. **85**, 1062 (1952).

K12. (Abstract withdrawn.)

K13. Optically Detected Magnetic Resonance in Rubidium Vapor. W. E. BELL AND A. L. BLOOM, *Varian Associates.*—The Dehmelt[1] technique of optical pumping and detection, used by us previously[2] on Na and K, has been extended to Rb at 30°C in argon buffer at 30-mm pressure. Signals have been observed from Rb^{85} and Rb^{87} in the earth's magnetic field, at frequencies of 235 kc and 350 kc, respectively. An interference filter was used to pass the $S_{\frac{1}{2}}\rightarrow P_{\frac{1}{2}}$ component and remove the $S_{\frac{1}{2}}\rightarrow P_{\frac{3}{2}}$ component of the incident light. The signal amplitudes are not in the ratio of isotopic abundances and it appears that Rb^{85} requires more light than Rb^{87} to "pump" to a given signal amplitude. With the most homogeneous magnetic field available the linewidth of Rb^{87} was observed to be about 130 cps. Structure caused by transitions between various ground state sublevels should be clearly resolved but no structure was seen; this, together with the narrow line width, is taken to indicate that we are approaching 100% population of the uppermost magnetic sublevel as predicted by theory. The effect of simultaneous magnetic resonance of both isotopes is to reduce the transmitted light intensity by about 20%.

[1] H. G. Dehmelt, Phys. Rev. **105**, 1487 (1957).
[2] W. E. Bell and A. L. Bloom, Phys. Rev. **107**, 1559 (1957).

K14. Optically Detected Hyperfine Resonances in Potassium Vapor. A. L. BLOOM AND W. E. BELL, *Varian Associates.*—Our earlier experiments in potassium have been extended to the hyperfine resonances ($\Delta F=1$, $\Delta m=\pm1, 0$). The setup employed a single unfiltered light beam, with the same absorption cell used previously being placed in a resonant cavity. Most of the allowed transitions have been observed in K^{39} at frequencies in the vicinity of 460 mc and the strongest lines have been seen in K^{41} in natural abundance at around 250 mc. The widths of the individual lines are not more than 500 cycles and are narrower than the composite Zeeman line at 350 kc which, however, contains unresolved structure. The relative intensities of the hyperfine lines do not agree entirely with predictions from Dehmelt's optical pumping theory. Instead it appears that the entire $F=1$ ground state group is partially depopulated relative to the $F=2$ group. Such an effect could be expected if the light were differentially absorbed by the hyperfine groups by their 5:3 multiplicity ratio, resulting in intensity differences available for pumping. The effect would, however, make it possible to see signals from unpolarized light. No such signals were seen. The transition $m=0\rightarrow m=0$ was not observable, as predicted by theory.

FRIDAY EVENING AT 7:30

Rickey's Restaurant

(L. I. SCHIFF presiding)

Banquet of the American Physical Society

After-Dinner Speech

Physicists, Dollars, and Sputnik. W. SHOCKLEY, *Director, Shockley Semiconductor Laboratories.*

SATURDAY MORNING AT 10:00

DINKELSPIEL

(C. TOBIAS presiding)

Invited Papers on Biophysics

L1. Development of Biophysics. ROBLEY WILLIAMS, *University of California, Berkeley.* (30 min.)

L2. Free Radicals and Antioxidants in Biological Systems. M. S. BLOIS, JR., *Microwave Laboratories, Stanford University.* (30 min.)

L3. Studies in Radiation Carcinogenesis. H. S. KAPLAN, *Stanford University School of Medicine.* (30 min.)

SATURDAY MORNING AT 9:30

Room 370

(C. L. SCHWARZ presiding)

Low-Energy Nuclear Physics, III

Invited Paper

M1. Recent Experiments with Medium-Energy Alpha Particles. G. IGO, *Stanford University.* (30 min.)

Contributed Papers

M2. Reactions of U^{238} with C^{12} Ions.* T. SIKKELAND,† A. GHIORSO, AND S. G. THOMPSON, *University of California, Berkeley.*—The excitation functions for some reactions of U^{238} with C^{12} in the energy range 45 to 105 Mev using the stacked foil technique have been measured. The $(C,4n)$ and $(C,6n)$ reactions are found to be consistent with the formation of a compound nucleus followed by neutron evaporation. The reactions which may be written as $(C,\alpha 4n)$ and $(C,\alpha 6n)$ occur mainly by the mechanism of stripping. In the curve for the $(C,\alpha 4n)$ indication is found for a breakup of the C^{12} ions into 3 alpha particles in the Coulombic field of the U^{238} nuclei. In this case one of the alpha particles is scattered and the two remaining are captured by the target nucleus. By using information obtained in bombardments of heavy nuclei with other particles the excitation functions for the heavy ion reactions are interpreted.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
† On leave from Jener, Norway.

M3. Nuclear Reaction Mechanisms in the Heavy Element Region from Angular Distributions of Heavy Recoils.* PAUL F. DONOVAN, BERNARD G. HARVEY, AND WILLIAM H. WADE, *University of California, Berkeley.*—The angular distribution of heavy recoils produced by the following reactions of Bi^{209} has been studied at energies ranging up to 48 Mev: $\alpha, 2n$; $\alpha, 3n$; $\alpha, 4n$; α, t; d, n; $d, 2n$; $d, 3n$, and d, p. Monte Carlo calculations based on a simple evaporation model have been done in the cases of the $\alpha, 2n$; $\alpha, 3n$; and $d, 3n$ reactions. These theoretical angular distributions have been compared with the experimental data. The agreement is good throughout the range of incident particle energies which may be expected from theory to produce reactions which proceed mainly by a compound nucleus mechanism.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

M4. Cross-Section Studies of the α, pn Reaction.* R. J. SILVA, B. G. HARVEY, AND W. H. WADE, *University of California, Berkeley.*—Excitation functions for the α, pn reaction on isotopes of selenium, palladium, lanthanum, and platinum have been obtained. These data, combined with published and unpublished data of other workers, show the general trends in the α, pn reaction from Fe^{54} to Cf^{249}. Most significantly, no sharp drop in the maximum value of the cross sections due to fission competition appears as the heavy element region is

entered as is the case with compound nucleus type reactions. The present data suggest a change from a compound nucleus formation mechanism, as shown by Ghoshal[1] for Ni^{60}, to some type of direct interaction mechanism leading to low excitation of the nucleus as Z of the target nucleus is increased. Experiments are underway to study more fully the mechanism of this reaction by studying the angular distribution of the product particles.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
[1] S. N. Ghoshal, Phys. Rev. **80**, 939 (1950).

M5. Reactions Induced in U^{238} with Helium Ions.* JOSEPH A. COLEMAN, T. DARRAH THOMAS, AND GLENN T. SEABORG, *University of California, Berkeley.*—Excitation functions have been measured for the production of U^{237}, U^{239}, Np^{238}, and Pu^{238} by bombardment of U^{238} with helium ions of energies up to 40 Mev. The reactions that produce U^{237}, U^{239}, and Np^{238} are thought to proceed by a mechanism involving a direct interaction between the helium ion and the target rather than by formation of a compound nucleus. From the cross sections for the reaction $U^{238}(\alpha,4n)Pu^{238}$ it is possible to calculate a mean value of Γ_n/Γ_f for the nuclides Pu^{239}, Pu^{240}, Pu^{241}, and Pu^{242}.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

M6. Studies on (α,t), (d,t), and (p,t) Reactions.* JOSÉ GONZALEZ-VIDAL AND WILLIAM H. WADE, *University of California, Berkeley.*—(α,t), (d,t), and (p,t) reactions have been investigated throughout the periodic table by bombarding stacked metal foils at the Berkeley 60-inch cyclotron and the 32-Mev proton linear accelerator. In the case of the (α,t) reactions there is evidence that most of the tritons are produced with high energies, thus suggesting a mechanism circumventing compound nucleus formations, however, the curve representing the integrated cross section *vs* Z raises with decreasing Z; this and the appearance of low-energy peaks in the individual excitation functions indicates that at low and intermediate values of Z the relative number of low-energy tritons increases. For the (p,t) and (d,t) reactions the data is not in disagreement with a single and double pickup mechanism respectively, for these reactions.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

M7. Angular Distribution of Tritons from the Al^{27} (α,t)Si^{28} Reaction.* WILLIAM H. WADE, HOMER CONZITT, AND JOSÉ GONZALEZ-VIDAL, *University of California, Berkeley.*—The angular distribution of tritons from the $Al^{27}(\alpha,t)Si^{28}$ reaction corresponding to the ground state and first excited state of Si^{28} have been measured for 48-Mev alpha particles. The ground-state transition shows a strong maximum centered about 0°, whereas the first excited state transition shows a minimum at 0° with a first maximum at ~7°. These results have been fitted to Butler's stripping theory.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

M8. New Rare Earth Isotopes.* KENNETH S. TOTH AND JOHN O. RASMUSSEN, *University of California, Berkeley.*—A series of bombardments on rare earth oxides using alpha particles from the Berkeley 60-inch cyclotron has led to the discovery of a number of new rare earth activities. These include two new alpha emitters, Dy^{155} (3.48 Mev) and Dy^{154} (3.35 Mev), whose half-lives are 5 and 13 hours, respectively. In addition, two new electron-capturing isotopes, Dy^{155} and Ho^{159} have been identified. The half-life of Dy^{155} has been found to be 10 hr and that of Ho^{159} about 33 min. Dy^{155} was discovered independently by Mihelich and co-workers[1] at the Oak Ridge National Laboratory. They made the isotope by means of a (p,pn) reaction on Dy^{156} and they list a half-life of 20 hr. A bombardment on Pr_2O_3 using nitrogen ions from the 60-inch cyclotron has resulted in the discovery of another isotope, Dy^{149}, whose half-life is about 8 min.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
[1] Mihelich, Harmatz, and Handley, ORNL report 63M57 (1957), to be published in *The Physical Review*.

M9. Helium Ion Induced Reactions of Th^{232}.* BRUCE M. FOREMAN, JR., AND GLENN T. SEABORG, *University of California, Berkeley.*—Th^{232} has been bombarded with helium ions from the Berkeley 60-inch cyclotron at energies varying from 18 to 46 Mev. Fission and spallation products have been separated radiochemically for the purpose of determining cross sections. Excitation functions are presented for the (α,an), (α,p), $(\alpha,pn+\alpha,d)$, $(\alpha,p2n+\alpha,dn+\alpha,t)$, $(\alpha,p3n+\alpha,d2n+\alpha,tn)$, and $(\alpha,4n)$ reactions. The reactions involving the emission of charged particles seem to proceed for the most part by direct interaction mechanisms. Fission competition seems to be considerably less than that observed in the bombardment of isotopes of heavier elements such as uranium and plutonium.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.

SATURDAY MORNING AT 9:30

Room 101

(W. SHOCKLEY presiding)

Solid-State Physics, II

N1. Small Angle X-Ray Scattering from Rolled Nickel.* W. T. OGIER, R. L. WILD, AND J. C. NICKEL, *University of California, Riverside.*—The diffuse x-ray scattering from rolled nickel oriented with the direction of roll in the plane of scattering has been observed to have a maximum intensity for a few percent reduction in thickness and to decrease according to the empirical relationship $I=5tI_0\exp(-240\theta-bR)$ for negligible foil thickness t (in cm), fractional reduction R, and corresponding main beam intensity I_0. Specimens prepared from 0.003-inch commercial annealed "A" nickel foil followed the above relationship over the range of observation from 6% to 45% in R and from 0.006 radian to 0.012 radian in total scattering angle θ for copper K_α radiation. The value of b varied from 4.3 at 0.006 radian to 2.4 at 0.012 radian. Scattering intensity when the direction of roll was oriented normal to the plane of scattering was lower and tended toward the parallel scattering intensity for large R. Scattering intensities at very small values of R depend critically on the amount of curl introduced by rolling. These observations seem to be in general agreement with the double Bragg scattering mechanism proposed by Beeman and associates.[1]

* Supported in part by the Research Corporation.
[1] M. B. Webb and W. W. Beeman, Bull. Am. Phys. Soc. Ser. II 1, 138 (1956).

N2. Cyclotron Resonance in Metals. D. N. LANGENBERG, A. F. KIP, AND B. ROSENBLUM, *University of California, Berkeley.*—Results of recent observations of cyclotron resonance at 24 kmc/sec in metals will be discussed. Well-defined resonances showing many subharmonics of the type predicted by Azbel and Kaner[1] have been observed in tin.[2] Magnetic field dependent absorption has also been seen in copper. Resonances have been found for static magnetic fields at angles as large as thirty degrees from the surface. The maximum angle has been predicted to be considerably smaller than this. A strong variation of absorption with magnetic field has been observed in all of the metals studied at fields less than 100 oersteds. This effect does not appear to have been noted in other work on cyclotron resonance in metals.

[1] M. Ia. Azbel and E. A. Kaner, J. Exptl. Theoret. Phys. (U.S.S.R.) **30**, 811 (1956). [English translation: Soviet Phys. JETP **3**, 772 (1956)].
[2] Kip, Langenberg, Rosenblum, and Wagoner, Phys. Rev. (to be published).

N3. Optical Constants of Evaporated Germanium. ROY F. POTTER, *U. S. Naval Ordnance Laboratory, Corona, California.*—Films of Ge, varying in thickness from 0.3 to 3 microns, have been prepared on glass and sapphire substrates in a conventional evaporation apparatus, and transmission patterns obtained with a Perkin-Elmer Model 21 spectrophotometer. The indices of refraction and the absorption coefficients can be obtained from transmissivity measurements with the aid of formulas developed by Brattain and Briggs[1] who considered the refractive index of the substrate as well as that of air. From the relative values of the maximum and minimum transmission due to interference effects, the index of refraction n can be determined in a non-dispersive region. A film 2.7 μ thick had an index which varied from 3.8 at 4.0 μ to 4.2 at 1.25 μ. The film thickness was obtained from the interference pattern maximum, using the relationship $2nd=m\lambda$, where m is an integer. From the known dimensions and its mass the film density was determined, and all determinations were less than that of the bulk material. The absorption coefficients were also determined between 1.0 and 4.0 μ. A tail of absorption extends beyond 4.0 μ, which is attributed to Rayleigh scattering resulting from the imperfect character of the film. When this scattering is subtracted, an absorption edge at 0.8 ev is apparent. A shift of this edge to higher values at lower temperatures has also been noted.

[1] W. H. Brattain and H. B. Briggs, Phys. Rev. **75**, 1705 (1949).

N4. Optical Constants of Germanium: 3600 A to 7000 A. R. J. ARCHER, *Bell Telephone Laboratories* (introduced by M. M. Atalla).—Except for one previous work, with which the present results disagree, this is the first measurement of the optical constants of single-crystal Ge in the visible. The constants were obtained from measurements of the ellipticity of reflected polarized light corrected for surface film effects. Mechanically polished and etched surfaces gave the same values, which were independent of the angle of incidence. The real part of the refractive index has maxima of 5.66 at 6000 A and 4.24 at 3900 A. The extinction coefficient has a maximum of 2.3 at 4900 A and another just outside the range of the measurements at about 3100 A with a value of about 3.3. The real and imaginary parts of the complex dielectric constant (extrapolated with values from previous workers) are consistent with the Kramers-Kronig relations and with the accepted value for the statical dielectric constant. If the beginnings of the maxima in the absorption curve are identified, as speculation, with the thresholds for direct transitions in k space between valence band and the first two conduction levels at $k=0$, the corresponding photon energies agree approximately with Herman's calculated values for the band separations.

N5. Shift of Photoconductive Peak with Polarization in CdS.* R. L. KELLY, *Stanford Research Institute.*—The wavelength of the peak of photoconductivity in CdS varies as the polarization of the incident light changes. The shift has been measured in several crystals and the results fitted to sine curves of the form

$$\lambda(\text{peak})=\lambda_0+A\sin 2(\alpha-\alpha_0),$$

where A is the amplitude of the shift and α is the angle of polarization of the incident light compared to some crystal dimension. The minimum value of λ(peak) occurs when the light is polarized parallel to the c axis. The wavelength λ_0, which is approximately the peak wavelength for unpolarized light, shows a rough dependence on the crystal thickness. The amplitude A has values of 12–23 A.

* This research was supported by the Physical Sciences Division Research Committee of Stanford Research Institute.

N6. Transmissivity and Reflectivity of Sn Films in the Vacuum Ultraviolet.* W. C. WALKER† AND O. P. RUSTGI, *University of Southern California.*—In order to observe the optical effects predicted by the Bohm-Pines theory,[1] the transmissivity and reflectivity of evaporated tin films were measured in the vicinity of the expected free electron plasma oscillation energy, i.e., near 12 ev. Measurements of transmissivity for unbacked films of the order of 1000 A thick showed a marked increase beginning near 14 ev and continuing to the limit of the measurements at 22 ev. For a 750 A thick film this increase ranged from about 0.3% at 14 ev to 20% at 21.5 ev. Data obtained on films evaporated on a glass substrate showed that the reflectivity decreases substantially before the onset of noticeable transmission. The present measurements will be compared to similar ones on aluminum previously reported.[2]

* The support of the Office of Ordnance Research is gratefully acknowledged.
† Presently at the Physical Science Department, University of California, Santa Barbara College.
[1] D. Pines, in *Solid State Physics*, edited by F. Seitz and D. Turnbull, (Academic Press, Inc., New York, 1955), Vol. 1, p. 437.
[2] Walker, Samson, and Rustgi, Reported at the American Physical Society meeting, Boulder, Colorado, 1957, (post-deadline paper); to be published in J. Opt. Soc. Am.

N7. Field Emission Microscope Studies of Silicon Crystals.* RICHARD L. PERRY, *Linfield Research Institute* (introduced by Ernest G. Brock).—The surfaces of silicon crystals have been studied using the electron emission patterns obtained from silicon fields cathodes in field emission microscope tubes.[1] Patterns with considerable symmetry and detail were obtained after severe heating of the cathode surfaces. The patterns are sufficiently detailed for recognition of the crystallographic orientation of the emitting crystals and for identification of polycrystalline samples with their associated grain boundaries. When it was found that the usual etching solutions (such as the CP-4 solution) did not produce the smooth symmetrical needle-shaped silicon cathodes required for field emission studies, techniques were developed to obtain the desired cathode geometry. These techniques will be discussed.

* This work is supported by the Bureau of Ships, Department of the Navy.
[1] Dyke, Trolan, Martin, and Barbour, Phys. Rev. **91**, 1043 (1953).

N8. Anomalous Nuclear Magnetic Resonance of B^{11} in Boron Carbide.* A. H. SILVER† AND P. J. BRAY, *Brown University.*—An annealed single crystal of boron carbide has been investigated at a B^{11} Larmor frequency equal to 17.6 Mcps. At this frequency, the previously reported[1] $m=\frac{1}{2}\rightarrow-\frac{1}{2}$ resonances for the normal boron crystallographic positions[2] $6h_1$ and $6h_2$ coalesce into one resonance line. An anomalous line with an orientation dependent resonance frequency is also observed. The frequency shift is attributed to a second-order quadrupole perturbation with $eqQ=5.58\pm0.02$ Mcps and

$\eta = 0$. The Z principal axis coincides with the trigonal (c) axis. The boron atoms contributing to this anomalous line are believed to be substituted in the crystallographic 1*b* position, i.e., in the center of the linear group of three atoms previously believed to be carbon. This assignment is based upon calculation and measurement of the integrated line intensity, the line width as a function of orientation, and the quadrupole coupling constant. The presence of small angle grain boundaries has been detected through variations of the line width with orientation.

* Research supported by the U. S. Atomic Energy Commission.
† Present address: Scientific Laboratory, Ford Motor Company, Dearborn, Michigan.
[1] A. H. Silver and P. J. Bray, Bull. Am. Phys. Soc. Ser. II, 1, 216 (1956).
[2] Clark and Hoard, J. Am. Chem. Soc. 65, 2115 (1943).

N9. Nuclear Spin Relaxation Times in Metals. A. G. ANDERSON* AND A. G. REDFIELD, *IBM Watson Laboratory.*—Nuclear spin relaxation times have been measured in lithium, sodium, copper, and aluminum between zero and 1000 gauss and between 1.1°K and 4.2°K. The method used was similar in principle to that of Ramsey and Pound.[1] In these metals the zero field relaxation time has a value of between 0.3 and 0.5 times the high field value. The high field relaxation times T_1 are in reasonable agreement with Korringa's theory[2]; the field dependence of T_1 is in good agreement with theory[3] for lithium and sodium, but in only qualitative agreement for aluminum and copper. Measurements in superconducting Al^{27} give a drop in T_1 of from 0.52 sec at 1.2°K to 0.25 sec at 1.1°K in reasonable agreement with the reported data of Hebel and Slichter.[4]

* Also at New York University.
[1] N. F. Ramsey and R. V. Pound, Phys. Rev. 81, 278 (1951).
[2] J. Korringa, Physica 16, 601 (1950).
[3] A. G. Redfield, IBM Journal 1, 19 (1957).
[4] L. C. Hebel and C. P. Slichter, Phys. Rev. 107, 901 (1957).

N10. Hyperfine Interactions in Metal Ammonia Solutions.* W. E. BLUMBERG, *University of California, Berkeley* (introduced by E. L. Hahn).—Wave functions have been obtained for the electrons in metal ammonia solutions by a variational procedure from a potential well based on the monomer proposed by Becker, Lindquist, and Alder.[1] These wave functions have been used to calculate the expected Knight shift in the region <0.5 molar. The results have been compared with the experimental values of McConnell and Holm[2] for the Knight shifts of Na and N in sodium-ammonia solutions and agree quite favorably. In particular, these calculations show that the N shift will decrease with dilution, while the Na shift will increase with dilution, between 0.5 and 0.03 molar. Below 0.03 molar, the Na shift should decrease with increasing dilution. The H shift is shown to be less than 0.02 gauss for all concentrations <0.5 molar, giving an explanation why McConnell and Holm could not observe it.

* Supported by the U. S. Office of Naval Research and the National Security Agency.
[1] Becker, Lindquist, and Alder, J. Chem. Phys. 25, 971 (1956).
[2] H. M. McConnell and C. H. Holm, J. Chem. Phys. 26, 1517 (1957).

N11. Nuclear Specific Heat of Cobalt Metal. V. ARP, N. KURTI,* AND R. PETERSEN, *University of California, Berkeley.*—We have measured the specific heat of cobalt metal in the temperature range 0.3 to 1.0°K and evaluated the contribution from nuclear polarization. An 8-g polycrystalline sample was cooled in a conventional demagnetization cryostat. Measured amounts of heat were introduced via a manganin resistance wire wrapped around the sample, and temperature was measured by means of a calibrated carbon resistor. The results can be expressed

$$(C/R)\times 10^4 = (6.2/T^3) + 5.6T$$

where the first term is the nuclear polarization contribution, and the second is the usual conduction electron specific heat. The nuclear contribution seems to be in good agreement with a value deduced[1] from anisotropy of γ radiation emitted by polarized Co^{60} nuclei in a single crystal sample. Results will be discussed in terms of an appropriate spin Hamiltonian.

* On sabbatical leave from Clarendon Laboratory, Oxford, England.
[1] Grace, Johnson, Kurti, Scurlock, and Taylor, Bull. Am. Phys. Soc. Ser. II, 2, 136 (1957).

N12. Creep Behavior of BeO. R. CHANG AND P. ROMO, *Atomics International.*—Studies of the instantaneous creep rates of polycrystalline BeO upon sudden changes of temperature up to 1750°C yielded activation energies of 110 000 to 120 000 calories/mole. Polygonization took place in polycrystalline BeO during creep in the temperature range 1500 to 1600°C and the stress range 1 to 2×10^7 dynes/cm^2. At higher temperatures, creep of BeO gave rise to recrystallization. Estimations from the widths of Debye spots using a microbeam x-ray diffraction technique (taken from specimens crept at 1550°C and 1.5×10^7 dynes/cm^2 to a total strain of 1.3%) yielded a dislocation density of the polygonized structure of approximately 4×10^7 lines/cm^2. Assuming that all the dislocations are edge-type, this dislocation density corresponds to a stored energy of about 0.8×10^6 ergs/cm^3. The total work done to the specimen upon straining 1.3% at 1.5×10^7 dynes/cm^2 is 2.0×10^6 ergs/cm^3, indicating that about 40% of the total energy is stored in the specimen. Polycrystalline BeO often exhibited an anomalous creep behavior—"negative" creep—in the temperature range 1500 to 1600°C. An interpretation of this behavior in terms of polygonization and recrystallization of the material during creep will be described.

N13. Thermal Gradient Self-Diffusion in Metals. W. A. BRAMMER, *Atomics International.*—If self-diffusion in certain metals is via a vacancy mechanism, then to a first approximation such metals when subjected to a large temperature gradients should show a net mass transport in a direction dictated by the relative magnitudes of the activation energies of formation and migration of vacancies, and at a rate which is proportional to their magnitude differences. Attempts have been made to demonstrate this phenomena in a typical face-centered-cubic metal (copper) and a typical body-centered-cubic metal (iron) by placing Kirkendall-type markers perpendicular to the large temperature gradients (approximately 2500°C/cm) and looking for changes in the marker spacings. Since no marker movement has been observed after extensive runs with iron and less extensive runs with copper, several explanations can be offered: (1) the fortuitous situation that $|Ef - Em| < 0.01$ ev; (2) the vacancy mechanism of self-diffusion is not operative in these materials (certainly a possibility for body-centered iron); (3) the simple theory is too naive and does not adequately represent the situation.

N14. Recovery of Electrical Resistivity of Cu, Au, and Ni Following Cold Work at 4°K. C. J. MEECHAN AND A. SOSIN, *Atomics International.*—Annealed Cu, Au, and Ni wires were cold worked in liquid helium and then pulse annealed for 3 minutes at 15°K intervals up to 80°K. The recovery of the induced electrical resistivity change was measured throughout this temperature range. No well-defined recovery stage was observed in this temperature range such as is found following electron, deuteron, or neutron bombardment. Continuous recovery is observed commencing below 15°K. For a given amount of cold work, the ratio of the amount of resistivity recovery between 4°K and 80°K to the total induced resistivity is a constant for all the metals observed. A mechanism for this recovery involving association of impurity with Frenkel defects will be discussed.

N15. Recovery Kinetics of Cold-Worked Nickel. A. SOSIN AND J. A. BRINKMAN, *Atomics International.*—The recovery of

pure (99.98+%) nickel following cold working at room temperature has been studied using electrical resistivity measurements with the sample immersed in a liquid helium bath. Three well-defined stages are found: Stage III centered at 90°C, Stage IV centered at 275°C, and Stage V associated with recrystallization. These are apparently analogous to Stages III, IV, and V in copper.[1] The Stage III recovery is characterized by a diffusion-type kinetics with an activation energy of about 1.20 ev. Stage IV recovery seems to possess a mixture of processes one of which corresponds to a diffusion-type kinetics. These data, plus the data of Clarebrough *et al.*,[2] are interpreted in terms of interstitial migration in Stage III and vacancy migration in Stage IV with dislocations acting as dominant sinks in both stages. This work was done in large part by L. Rachal.

[1] H. G. van Bueren, thesis, University of Leiden, 1956.
[2] Clarebrough, Hargreaves, Mitchell, and West, Proc. Roy. Soc. (London) A215, 507 (1952).

Saturday Morning at 9:45

Room 100

(R. Hofstadter presiding)

High-Energy Electron Physics

O1. Multiple Scattering of 600-Mev Electrons by a Thin Aluminum Foil.* R. C. Smith, R. E. Taylor, F. R. Tangherlini, and R. F. Mozley, *Stanford University.*—A measurement has been made of the multiple scattering of a collimated beam of 600-Mev electrons by a 3-mil (0.0205 gm/cm²; 8.6×10^{-4} rad length) aluminum foil. The scattered electrons pass through a glass plate at a distance of 40 feet and the location of the scattered electrons is determined by a densitometer measurement of the darkening of the plate. The linearity of darkening is established by making a series of similar measurements with different total numbers of incident electrons. The resulting multiple-scattering curve has a mean width of 0.70 ± 0.05 mc^2/E_0. The accuracy of measurement does not allow it to be distinguished from a gaussian. This number is in agreement with the 0.74 mc^2/E_0 value predicted by Molière theory.

* Supported by the joint program of the Office of Naval Research, the U. S. Atomic Energy Commission, and the Air Force Office of Scientific Research.

O2. Effects of Finite Nuclear Size in Electrodisintegration Experiments.* W. C. Barber, *Stanford University.*—The usual expressions giving the cross section for electrodisintegration reactions in terms of the photodisintegration cross sections are not valid when the nuclear size is comparable with the wavelength associated with the momentum transfer.[1] Measurements of the ratio of the yields of C^{11} produced by the $C^{12}(e,e'n)$ and $C^{12}(\gamma,n)$ have been made using primary electrons of energy from 24 to 150 Mev. At the higher energies a comparison of this ratio with theory requires consideration of the finite nuclear size. An approximate size correction has been included in the theory with the result that the comparison of experiment and theory is consistent, at all primary energies, with the interpretation that the transitions producing the reactions are predominantly electric dipole. A similar comparison of theory and the experimental yield ratios of the reactions $F^{19}(e,e'2p)N^{17}$ and $F^{19}(\gamma,2p)N^{17}$ measured by Reagan[2] indicate these transitions are predominantly electric quadrupole.

* Supported by the joint program of the Office of Naval Research, the Atomic Energy Commission, and the Air Force Office of Scientific Research.
[1] R. H. Dalitz and D. R. Yennie, Phys. Rev. 105, 1598 (1957).
[2] Daryl Reagan, Phys. Rev. 100, 113 (1955).

O3. Form Factor Investigation of the Neutron by High-Energy Electron Scattering.* M. R. Yearian and R. Hofstadter, *Stanford University.*—The magnetic form factor of the neutron can be investigated through a study of the inelastic continuum of electrons scattered from deuterons at high momentum transfers.[1] The inelastic spectrum has been compared with elastic electron scattering from free protons at 500 Mev (75°–135°) and at 600 Mev (135°). The inelastic spectra have been corrected for electron-pion production, for contamination by negative pions, and for shape distortion due to bremsstrahlung. The shapes of the spectra are roughly similar at all angles and agree well with predictions of a theory due to Jankus.[2] The present results are: (1) irrespective of the details of applicable theories, the neutron's magnetic cloud is extended and is not a point. (2) The neutron's magnetic size and shape are approximately the same as those of the proton. (3) The differences between the neutron and the proton can be determined from the present data upon development of an accurate theory of electrodisintegration of the deuteron. Such a theoretical calculation is now under investigation by Blankenbecler.[3]

* Supported by the Joint program of the Office of Naval Research and the U. S. Atomic Energy Commission, and by the Office of Scientific Research Air Research and Development Command.
[1] R. Hofstadter, Revs. Modern Phys. 28, 214 (1956), see Sec. VI.
[2] V. Z. Jankus, Phys. Rev. 102, 1586 (1956).
[3] R. Blankenbecler (to be published).

O4. Improved Sum Rule for Electron-Deuteron Scattering. Richard Blankenbecler.* *Stanford University.*—Recent experimental results on electrodisintegration of the deuteron[1] promise to yield information on the electromagnetic structure of the neutron. An improved sum rule relating the total scattering from the deuteron to the scattering from free nucleons in the high-energy limit has been derived. The result is

$$\sigma_T = D(x)[\sigma_P + \sigma_N],$$

where $D(x)$ is a power series in the derivative with respect to the relative momentum between outgoing nucleons, and the coefficients are moments of the deuteron momentum distribution. After the derivatives are performed, quantities are evaluated at their free scattering values. If binding is neglected, $D=1$. Assuming Gaussian nucleons of equal radii and a reasonable deuteron model, $D=1.12$ for 470-Mev electrons at 135°. Further numerical results and their implications on the neutron size will be discussed.

* Predoctoral National Science Fellow.
[1] R. Hofstadter, Revs. Modern Phys. 28, 214 (1956).

O5. Nucleon Charge and Moment Distributions.* L. I. Schiff, *Stanford University.*—The apparent failure of charge symmetry in the structures of the proton and the neutron[1] is

examined in the light of the possibility that the neutron charge density has zero volume integral and zero mean-square radius, but is not identically zero. Such a distribution must have at least two zeros as a function of radius. A simple analytic form is assumed that has a positive maximum at the origin, followed by a negative region and then a very small positive region. The proton charge density is then chosen so that when it is added to the neutron density, only the central positive maximum (the nucleon core distribution) remains. Proton and neutron magnetic moment densities are assumed to have the same form, and it makes little difference whether these have the simple shape used in earlier studies, or the shape assumed here for the proton charge, which has one change of sign. It is then possible to fit the electron-proton and electron-deuteron elastic scattering data. The total electron-deuteron inelastic (break-up) scattering cross section is computed to be about 25 percent less than found experimentally.[2] While these distributions can be regarded as meeting the requirements of charge symmetry, they lead to a core distribution that has the same root-mean-square radius as that of the proton charge, although it has a more concentrated appearance.

* Supported in part by the Air Force Office of Scientific Research.
[1] Yennie, Lévy, and Ravenhall, Revs. Modern Phys. **29**, 144 (1957).
[2] M. Yearian and R. Hofstadter, Bull. Am. Phys. Soc. Ser. II, **2**, 389 (1957); R. Blankenbecler, *ibid.*, p. 389.

O6. Inelastic Scattering of 500-Mev Electrons from Li^6 and Li^7.* U. Meyer-Berkhout and Robert Hofstadter, *Stanford University.*—500-Mev electrons have been scattered from enriched Li^6 and ordinary Li^7 between scattering angles of 60° and 135° in the laboratory system. The cross section integrated over the inelastic continuum at these large momentum transfers has been compared with the free proton cross section at the corresponding angles. The results to be discussed are obtained by assuming that the scattering from the bound nucleons in first approximation can be considered as incoherent. The measured ratios, σ_{Li}/σ_P, seem to indicate that protons and neutrons in lithium make comparable contributions to the magnetic scattering at the larger angles. It is difficult at present to find the neutron's actual contribution to the cross section, since theoretical estimates of corrections, allowing for the momentum distribution of the nucleons, final state interaction, meson production and exchange, are uncertain. Therefore, only the quantity $R=1/N[(\sigma_{Li}/\sigma_P)-3]$, where $N=3, 4$ for Li^6, Li^7, respectively, has been derived from our data. R should be equal to σ_N/σ_P, if incoherency applies and if the corrections are negligible. If we set tentatively $\sigma_N/\sigma_P=R$, σ_N/σ_P is found to be (1.0 ± 0.4) at 135°, 500 Mev, and decreases to $(0.5_5\pm0.2)$ at 60°, 500 Mev.

* Supported by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission, and by the Office of Scientific Research Air Research and Development Command.

O7. Scattering of 420 Mev Electrons from Some Nuclei of the First p-Shell.* H. Ehrenberg, U. Meyer-Berkhout, R. Hofstadter, D. G. Ravenhall, and S. E. Sobottka, *Stanford University.*—Measurements of the elastic scattering cross sections of 420 Mev electrons at various scattering angles have been performed for C^{12} and O^{16} and furnish new information on the shape and size of those nuclei. The experimental results were obtained as part of a program to study the charge distributions of the nuclei of the first p-shell and are compared with the predictions of a theoretical phase shift analysis derived for the harmonic well independent particle model of the nucleus. Pronounced diffraction minima in the angular distributions were observed for C^{12} and O^{16}. The new data on C^{12} are in excellent agreement with what one would expect from earlier measurements performed at 183 Mev. Best fits of the experimental data with theoretical angular distributions make it possible to check the shell model predictions for the parameter α related to the number of protons in the first p-shell and furthermore give the value of the parameter a_0, which is related to the curvature of the infinite harmonic well. a_0 varies within the p-shell. Values of α and the rms radius of the charge distribution used in the best fits will be given. The freedom in choosing those parameters will be discussed. Data on Li^6 and Be^9 will be included in the discussion.

* Supported by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission, and by the Office of Scientific Research, Air Research, and Development Command.

O8. Form Factor Studies of the Proton at High Energies.* F. Bumiller and R. Hofstadter, *Stanford University.*—Elastic electron scattering experiments have been carried out against protons in CH_2 at energies of 500, 550, 575, 600, 650 Mev between laboratory scattering angles of 75° and 135°, in order to investigate finite size effects in the proton.[1] The new experiments attempt to distinguish between several different models of density distribution fitting the earlier data. Two methods of comparison with phenomenological models have been used. The first (I) employs a plot of F^2 *versus* q^2 where $F_1=F_2=F$.[1] The second method (II) concentrates on the experimental ratio of $\sigma_{75}°/\sigma_{135}°$, which is a sensitive index distinguishing between the various models and, furthermore, does not require a knowledge of absolute cross sections. The results of methods (I), (II) are as follows: (a) the present experiments are consistent with the earlier ones[1] as far as the earlier ones go. (b) The newer data distinguish between the models previously proposed. (c) The most favorable case among the exponential, Gaussian, hollow exponential, and Yukawa I, II models is the exponential with rms size $r_e=r_m=0.80\times10^{-13}$ cm. (d) Absolute cross sections are in good agreement with the exponential model.

* Supported by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission, and by the Office of Scientific Research, Air Research, and Development Command.
[1] E. E. Chambers and R. Hofstadter, Phys. Rev. **103**, 1454 (1956).

O9. Electron Scattering Study of Li^6.* R. Hofstadter and G. R. Burleson, *Stanford University.*—The nucleus Li^6 has been investigated with electrons of energy 426 Mev scattered in the angular range 33°–50°. Elastically scattered electrons are resolved from electrons which have been scattered with excitation of the first level, at 2.189 Mev, and higher levels. To achieve this resolution in the presence of large inelastic cross sections, the elastic peaks were approximately 0.25% wide (full width) at half maximum. An analysis of the angular distribution has been carried out with the Born approximation and several possible nuclear models. An independent particle shell model, using an infinite harmonic well, fits the experimental data if the rms radius is chosen to be $2.2\pm0.2\times10^{-13}$ cm. A Gaussian will also fit moderately well with a similar radius, but this charge distribution is not significantly different from that of the shell model. Other models will be discussed.

* Supported by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission, and by the Office of Scientific Research, Air Research, and Development Command.

O10. Sum Rules for Inelastic Electron Scattering.* S. D. Drell and C. L. Schwartz, *Stanford University.*—Sum rules are constructed for the analysis of inelastic electron scattering at high energy (~150 Mev) from light nuclei. Effects taken into account are: nucleon charge, recoil, and magnetic-moment currents; exchange currents; finite nucleon size; nuclear center-of-mass motion. The form of the sum rule for fixed electron-scattering angle is complicated because of the kinematical connection between the momentum of the scattered electron and the energy of the final nuclear state. A more natural sum rule results for electron scattering with

fixed momentum transfer. The energy region below meson threshold to which we restrict these considerations for reasons of ignorance of a relativistic nuclear description, precludes the possibility of learning about internucleon correlations (beyond the Pauli principle) from this work. However, it appears that a sensitive test of the role of exchange currents in the nucleus is provided by a sum rule for the energy-weighted cross section

$$\sigma_E = \int_{|q|=\text{const}} \epsilon\sigma(\epsilon,\mathbf{q})d\epsilon.$$

* Supported in part by U. S. Air Force Office of Scientific Research Development Command.

O11. Inelastic Scattering of Electrons in Hydrogen.* E. A. ALLTON AND W. K. H. PANOFSKY, *Stanford University.*—Inelastic scattering in hydrogen leading to pion production gives additional information as compared to photopion production since: (a) Longitudinal matrix elements contribute to the process. (b) The relation between production by real and virtual photons is different depending on the multipole order of the meson-nucleon system. (c) Contrary to the situation in photoproduction, the momentum transfer to the meson-nucleon system can exceed the energy transfer; "structure" effects in the matrix elements can thus be studied. All these effects are largest at large electron angles. For this reason, a procedure has been developed and tested to study the inelastic scattering process by observing the scattered electrons at a large angle. The contributions from secondary electrons due to large-angle bremsstrahlung can be calculated theoretically and are subtracted. Contributions due to converted γ rays from π^0 production, due to electron-positron pairs and due to high-energy π^- mesons produced by real and virtual photons, can be eliminated by studying the electron yield as a function of a radiator placed in the primary electron beam. This method has been tested and gives internally consistent results. Absolute cross sections are obtained by comparison with the elastic cross sections measured in the same apparatus.

* Supported by the joint program of the Office of Naval Research, the U. S. Atomic Energy Commission, and the Air Force Office of Scientific Research.

O12. Determination of the Form Factor of the Difference between the Proton and Neutron Magnetic Moments.* W. K. H. PANOFSKY AND E. A. ALLTON, *Stanford University.*—The method of the preceding paper has been used to study inelastic electron scattering with the primary and secondary electron energies programed against each other to maintain the energy of the pion-nucleon system at the "resonance" energy. At this energy setting and a laboratory angle of 75° for the scattered electron, the momentum transfers can be varied from ~200 to 470 Mev/c, thus exploring the form factor for the matrix element in question. This measurement can give independent evidence concerning the extent in space of the proton and neutron magnetic moment distributions,[1] since the Chew-Low and dispersion theory matrix elements are proportional to the algebraic difference in the proton and neutron magnetic moments. Under the conditions mentioned the theoretical value[2] for a point nucleon of the cross section for inelastic scattering of an electron leaving the proton-pion system at the energy corresponding to the $\frac{3}{2}$, $\frac{3}{2}$ resonance is 3.0×10^{-31} cm^2 sterad^{-1} Mev^{-1}. The experimental measurements deviate progressively from this value toward $(1.35\pm0.13)\times10^{-31}$ cm^2 sterad^{-1} Mev^{-1} at a momentum transfer of 470 Mev/c. The figure is in agreement if both the neutron and proton are given radii corresponding to the electromagnetic radius[3] of the proton.

* Supported by the joint program of the Office of Naval Research, the U. S. Atomic Energy Commission, and the Air Force Office of Scientific Research.

[1] Pointed out by S. P. Fubini (private communication).
[2] R. H. Dalitz and D. R. Yennie, Phys. Rev. **105**, 1598 (1957).
[3] E. E. Chambers and R. Hofstadter, Phys. Rev. **103**, 1454 (1956).

SATURDAY AFTERNOON AT 1:30

Room 100

(F. BLOCH presiding)

Invited Papers on Nuclear and Paramagnetic Resonance

P1. Electron Spin Resonance of Atomic and Molecular Free Radicals Trapped at Liquid Helium Temperature. C. K. JEN, *Applied Physics Laboratory, The Johns Hopkins University.* (30 min.)

P2. Experiments with Spin Precession Magnetometers. MARTIN E. PACKARD, *Varian Associates, Palo Alto, California.* (30 min.)

P3. Use of Optical Orientation in Gas Cell Atomic Standards. THOMAS R. CARVER, *Palmer Physical Laboratory, Princeton University.* (30 min.)

P4. New Experimental Techniques in Pulsed Magnetic Resonance. E. L. HAHN, *University of California, Berkeley.* (30 min.)

SATURDAY AFTERNOON AT 1:30

Room 101

(J. LEPORE presiding)

Theory

Q1. Theory of the Weak Interactions. RICHARD P. FEYNMAN AND MURRAY GELL-MANN, *California Institute of Technology.*—All weak interactions are described in terms of a universal interaction among pairs of particles, one charged and one neutral, such as $(p n)$, $(e\nu)$, $(\mu\nu)$, $(p\Lambda)$. The wave functions of e^-, ν, and μ^- always appear multiplied by $1+\gamma_5$. The neu-

trino is thus longitudinal and spins to the left. The interaction in μ decay has to be $V-A$ and positrons from $\pi^+\to\mu^+\to e^+$ spin to the right. For the baryons there are two possibilities: either the wave functions of all baryons always appear multiplied by $1+\gamma_5$ or else this is true of all antibaryons. The interaction in β decay is then $V-A$ or $V+A$, respectively. This is at present in conflict with some experiments, but agrees with most. Applications of the theory to the decay of strange particles will be discussed.

Q2. Phenomenological Potential for $\pi^- - P$ Scattering. MAX CHRÉTIEN, *Brandeis University.*—The characteristic features of $\pi^- - P$ scattering for π^- energies around 1 Bev are a considerable amount of backward scattering for the elastic processes and a large inelastic cross section. For $E_{\pi^-\,\mathrm{kin\,Lab}}\approx 1.3$ Bev the values are $\sigma_{\mathrm{inel}}\sim 20$ mb, $\sigma_{\mathrm{el}}\sim 10$ mb, $(d\sigma/d\Omega)(0^\circ)\sim 8$ mb/sterad, the backward scattering ($\vartheta_{\mathrm{cm}}>90^\circ$) B is 19% of the total elastic scattering. The latter figure cannot be described by a standard optical model (i.e., a uniform complex potential for $r<R$), as this gives B values of only 1–3% for R values compatible with the small angle scattering. The simplest potential capable of producing large B's is a complex well of depth V and radius R around a repulsive core V' of radius R'.[1] For $V'=\infty$ the calculation of the phase shifts is comparatively simple. The choice $V=-(25+30i)$ Mev, $R=1.18\times 10^{-13}$ cm, $R'=0.30\times 10^{-13}$ cm gives $\sigma_{\mathrm{inel}}=18$ mb, $\sigma_{\mathrm{el}}=10$ mb, $(d\sigma/d\Omega)(0^\circ)=10$ mb/sterad, $B=15\%$. It is very remarkable that a similar potential accounts for the essential features of the low energy scattering: The small s-wave and the large p-wave phase shifts. With a real potential (no inelastic processes) $V=-420$ Mev, the same R and $R'=0.7\times 10^{-13}$ cm one gets $\delta_s=0.04\eta$ and $\delta_p=0.09\eta$ for $\eta\ll 1$ in fair agreement with the experiment. The p-scattering cross sections shows a sharp peak around $E_{\pi^-\,\mathrm{kin\,Lab}}=300$ Mev, the s-scattering stays small up to $\sim$700 Mev.

[1] Such potentials were qualitatively discussed by several authors.

Q3. Large-Angle Pair Production and Quantum Electrodynamics at Small Distances.* J. D. BJORKEN,† S. D. DRELL, AND S. C. FRAUTSCHI,† *Stanford University.*—Electromagnetic pair production in hydrogen with large momentum transfer provides a test of the validity of quantum electrodynamics (QED) at distances $\lesssim 10^{-13}$ cm. Because of center-of-mass motion electron-electron (positron) scattering at present energies ($E_{\mathrm{Lab}}\approx 1$ Bev) is insensitive to distances $<10^{-13}$ cm, as are radiative corrections, such as the electron's anomalous magnetic moment. The electron-proton scattering experiments of Hofstadter show that QED is valid down to $\sim 10^{-13}$ cm at which distances effects of nucleon structure appear. Assuming the validity of QED for distances $\lesssim 10^{-13}$ cm, one can completely summarize the results of the electron-proton scattering experiments in two invariant functions of the four-momentum transfer, the proton's charge and moment form factors. The cross section for electromagnetic pair production in hydrogen is then known in terms of these two form factors, and the proton can be used, with known electromagnetic interactions, to fix the center-of-mass relative to the laboratory system. We have carried out a complete calculation, including radiative corrections, of large-angle pair production for photons incident on "Hofstadter" protons.

* Supported in part by U. S. Air Force OSRDC.
† National Science Foundation Predoctoral.

Q4. Evidence for Three-Body Vector Forces in Nuclei. ARNOLD M. FEINGOLD, *University of Utah.*—Pearse[1] has shown that one cannot fit the doublet splittings in Li^7, N^{15}, and O^{17} with a two-body spin-orbit (vector) force of fixed strength. It has been suggested previously[2] that the effective vector force in nuclei may be mainly three-body in character, representing certain higher order effects of the tensor force. A three-body force acts quite differently on a "hole" than on a particle—in particular, the ratio of the doublet splitting for a "hole" compared to that for a particle is much greater for a three-body vector force than for a two-body force. Thus one can easily fit the Li^7 and N^{15} doublet splittings with a properly chosen phenomenological three-body vector force. By a proper choice of the parameters of the vector potential, in particular the exchange nature of the potential and the relative amounts of two- and three-body vector forces, one can also fit simultaneously the doublet splitting of O^{17}.

[1] C. A. Pearse, Phys. Rev. 106, 545 (1957).
[2] A. M. Feingold, Phys. Rev. 105, 944 (1957).

Q5. Dispersion Theory of Proton Compton Scattering. JON MATHEWS AND MURRAY GELL-MANN, *California Institute of Technology and The RAND Corporation.*—The dispersion formalism for arbitrary momentum transfer has been applied to the problem of proton Compton scattering. Because of our lack of knowledge concerning the high-energy behavior of scattering amplitudes, alternative forms of the dispersion relations must be considered. Comparison with the results of a Chew-Low type of calculation[1] suggests a particularly simple model which, however, does not appear to be completely self-consistent. Problems of this and other models will be discussed, together with numerical predictions of the theory.

[1] Watson, Zachariasen, and Karzas, Bull. Am. Phys. Soc. Ser. II, 1, 383 (1956).

Q6. Perturbation Calculations in the Hydrogen Atom. CHARLES SCHWARTZ, *Stanford University.*—In standard notation, the first-order perturbation equation to be solved (yielding the second-order energy correction) is

$$(E_0-H_0)\psi_1=(H_1-E_1)\psi_0.$$

First the angular momentum components are separated out and for each radial equation the initial behavior r^l is factored out of ψ_1. For the case when H_0 represents a particle moving in a Coulomb field, the application of a Laplace transformation now reduces the problem to a first-order inhomogeneous differential equation. The desired results of any second-order perturbation problem can thus be put in integral form. This technique is applied to the evaluation of the nonrelativistic part of the Lamb shift (Bethe's mean logarithm) and the answer is gotten in the form of a double integral. A series expansion, evaluated numerically with machine help, gives results accurate to about eight figures for the $2s$, $2p$ states. The previously published evaluations are shown to be correct as far as the practically significant figures are concerned. Application of this technique to other problems involving radiative corrections to the Schrödinger wave functions of hydrogen, and the construction of simple approximate solutions will be discussed.

Q7. Soluble Relativistic Field Theory. WALTER THIRRING, *University of Washington.*—The theory of a self-coupled spinor field with $L^1=\lambda\bar{\psi}\psi\bar{\psi}\psi$ is solved in one space and one time dimension for rest mass zero of the particles. A solution is obtained by solving the problem of N particles scattering N^1 antiparticles via a δ function. This problem is similar to the one-dimensional spin-wave problem. With this result, a representation of the eigenstates of energy can be given. Some observable quantities are calculated and are found to be finite after renormalization. They can be expanded in powers of λ with a finite radius of convergence. Since the one-dimensional case is renormalizible in contradistinction to the three-dimensional one, one cannot compare this result with the realistic case. But it may reflect some properties of renormalizible three-dimensional theories.

Q8. Consolidated Variation-Perturbation Theory.* WILLIAM T. SIMPSON, *University of Washington,* AND HARRISON SHULL, *Indiana University.*—Second-order perturbation theory is extended to the case in which only the first member of the

expansion set is an eigenfunction of the comparison Hamiltonian H^0. The energy correction then becomes in matrix form: $W^2 = -\mathbf{H}_0'^*(\mathbf{H}^0 - W^0\mathbf{I})^{-1}\mathbf{H}_0'$. Explicit division of H into H^0+H' is unnecessary to evaluate the elements of $\mathbf{H}_0'$, since $\mathbf{H}_0' = \mathbf{H}_0$. The Hamiltonian is then regarded as divided implicitly so that a given variation function is an eigenfunction of the implicit H^0. An explicit division must be approximated, however, to calculate the elements of $\mathbf{H}^0$. It is shown that a satisfactory approximation for the comparison Hamiltonian H^0 is H itself. The approximate energy correction becomes: $R = -\mathbf{H}_0^*(\mathbf{H}-W\mathbf{I})^{-1}\mathbf{H}_0$. Further analysis shows that R is precisely the second- and third-order perturbation theory corrections combined, correct to terms in the fourth order. If the variation function is sufficiently good so that the perturbation is small and the expansion converges, systematic application of this formula leads to a consolidation of variation and perturbation theory in which R becomes a true remainder to a variation theory calculation.

* Supported by a contract with the Air Force Office of Scientific Research and by a grant from the Alfred J. Sloan Foundation.

Q9. Applications of Consolidated Variation-Perturbation Theory.* HARRISON SHULL, *Indiana University*, AND WILLIAM T. SIMPSON, *University of Washington*.—Consolidated variation-perturbation theory as outlined in the previous abstract is demonstrated in its application to two-electron systems, largely to the He atom. The expansion set used is the completely discrete set of associated Laguerre functions of single orbital exponent.[1] For this particular set, it is shown that the second-order result, $W^0+W^1+W^2$, is the same irrespective of the explicit choice of division of the nuclear attraction operator between the comparison Hamiltonian and the perturbation term. The explicit choice is important, however, since higher orders in the perturbation theory expansion become small only for an optimum choice. In particular, for $\psi^0 = 1s^1$, $Z=2$, $W^0 = -4.000$, $W^1 = +1.250$, $W^2 = -0.151$; whereas for $Z = 1.6875$, $W^0 = -2.848$, $W^1 = 0.000$, $W^2 = -0.054$.[2] The improvement becomes progressively more marked for the higher order terms. The systematic application of the remainder theorem to the variation method is shown in two examples: first, without approximation in connection with a He 20×20 matrix, and secondly in approximation for a much larger (136×136) He matrix.

* Supported in part by a contract with the Air Force Office of Scientific Research, and in part by grants from the Alfred J. Sloan Foundation, the National Science Foundation, and the Research Corporation.

[1] H. Shull and P.-O. Löwdin, J. Chem. Phys. **23**, 1362 (1955).

[2] Results for 20×20 case. Experiment is -2.904.

Q10. Time Reversal Invariance in Nuclear Forces and Angular Correlations.* B. A. JACOBSOHN AND E. M. HENLEY, *University of Washington*.—Gamma-gamma and alpha-gamma correlations from nuclei, the initial polarization of which may be caused by magnetic fields or a previous β decay, provide possible tests for the invariance of nuclear forces under time reversal (TRI). TRI implies a restriction on the matrix elements of an emission process whenever an exponential decay in time is a good approximation; it is then possible to construct physical observables for which TRI implies vanishing expectation values. In order to use direction-direction, circular polarization-direction, or linear polarization-direction correlations, the initial state must be at least linearly polarized, aligned, or third-order polarized, respectively; furthermore, in the first two cases two transitions are necessary, the first one of which must be mixed. We have also recast the expressions for the emission rate of polarized radiation from an arbitrarily oriented nucleus into a form more transparent to the relevant symmetries. Numerical formulas will be given for some cases of special interest.

* Supported in part by the U. S. Atomic Energy Commission.

Q11. Reciprocal Forces, Gravitation and Viewpoints. F. W. WARBURTON, *University of Redlands*.—The generalized negative gradient of potential energy of two electrical charges, including the retarded potential, not only provides the transverse electric field of the oscillating electric dipole by canceling the radial acceleration term; but it also cancels the velocity term for which direct experimental evidence is lacking. A small nonattenuating term describes radiation damping. Computation of another small "nonattenuating" term, expanded for a simplified model of a proton or electron as a stable rotating electric dipole, indicates that gravitation may be accounted for in terms of these variations in electric force. Emphasis is placed on the viewpoint that the form of electrodynamics need not be restricted by reference systems of the observers and the consequent transformations; but that a less subjective description in terms of relative motion of the charges is possible. Extremes of the phenomenalistic approach on the one hand, and of undue faith in "unexplained" postulates on the other, may be avoided by the less spectacular search for precise logic and physical meaning at each step.

Q12. Convergence of the *S* Matrix. S. GARTENHAUS AND D. R. YENNIE,* *Stanford University*.—Stimulated by the work of Caianiello, an investigation was made of the convergence, in powers of the coupling constant, of the field theoretic perturbation expansion of the elements of the S matrix. For a theory characterized by a coupling linear in the boson field, it has been established that if a cutoff is introduced in momentum space, then the transition amplitude for a given process over a finite time interval is bounded term by term by an exponential series. Similarly, for a theory quadratic in the boson field, the matrix elements are bounded term by term by a geometric series and hence may converge only in a finite region. Unfortunately, the bounding series is given in terms of the unrenormalized coupling constant, and in addition the method does not allow the separation of the vacuum-to-vacuum amplitude from the diagrams of actual interest. Nevertheless, one is able to conclude from the convergence itself that large cancellations among diagrams must take place and that this latter feature may carry over to the more interesting theories.

* Now at the University of Minnesota.

SATURDAY AFTERNOON AT 1:30

Room 370

(G. GOLDHABER presiding)

Low-Energy Nuclear Physics, IV

R1. Alpha and Gamma Spectra of Cm^{243}.* FRANK ASARO, S. G. THOMPSON, F. S. STEPHENS, JR., AND I. PERLMAN, *University of California*.—The alpha spectrum of Cm^{243} has been investigated with uniform-field and double-focusing magnetic alpha-particle spectrographs. Three sets of rotational levels in Pu^{239} were identified based on levels with energies and

Nilsson[1] assignments ($I_\pi, Nn_z\Lambda$) of 0 kev (1/2+, 631),[2] 286 kev (5/2+, 622)[2] and 392 kev (7/2−, 743). The alpha groups to the 1/2+ band (with spins and parities from 1/2+ to 11/2+) have energies and intensities of 6.061 (1%), 6.054 (5%), 6.005 (0.9%), 5.987 (6%), 5.900 (0.1%), and 5.872 Mev (0.5%). These intensities are interpreted as a mixture of hindered $L=2$ and $L=4$ alpha waves.[3] The 5/2+ band is populated by "favored"[3] or unhindered alpha decay, hence the Nilsson[1] assignments for the Cm^{242} ground state are also 5/2+, 622. The alpha-particle energies and intensities to the 5/2+, 7/2+, and 9/2+ members of this band are 5.780 (73%), 5.736 (11.5%), and 5.680 Mev (1.6%).

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
[1] S. G. Nilsson, Kgl. Danske Videnskab. Selskab Mat.-fys. Medd. **29**, No. 16 (1955).
[2] I. Perlman and J. O. Rasmussen, "Alpha Radioactivity" in *Encyclopedia of Physics* (Springer-Verlag, Berlin, 1957), Vol. XLII, p. 109.
[3] Bohr, Fröman, and Mottelson, Kgl. Danske Videnskab. Selskab Mat.-fys. Medd. **29**, No. 10 (1955).

R2. Decay Scheme of Cf^{249}.* F. S. Stephens, Jr., Frank Asaro, S. G. Thompson, and I. Perlman, *University of California, Berkeley.*—The gamma-ray spectrum of Cf^{249} has been studied with a NaI(Tl) scintillation spectrometer and the following gamma rays were observed: 394±4 kev, 72%; 340±4 kev, 15%; 255±3 kev, 2.5%; and 110±3 kev, (K x-rays), 7.5%. We are currently studying the alpha-particle spectrum on a double-focusing magnetic spectrograph, and tentative results are as follows: (α_x represents the alpha group populating a state of energy x) α_0, 1.9%; α_{55}, 1.1%; α_{134}, 0.4%; $\alpha_{197}(?)$, 0.08%; α_{328}, 3.3%; α_{361}, 3.0%; α_{387}, 1.2%; α_{394}, 83.7%; $\alpha_{422}(?)$, 0.5%; α_{449}, 4.4%; and α_{511}, 0.4%. Coincidence studies and alpha-particle gamma-ray angular correlation measurements have also been made. The data are interpreted in terms of three rotational bands in Cm^{245}, whose base states have the following energy and Nilsson[1] level assignments ($I_\pi, Nn_z\Lambda$): 0 kev (7/2+, 624), 255 kev (5/2+, 622), and 394 kev (9/2−, 734). The alpha decay to the 394-kev band is interpreted as "favored" alpha decay so that the Nilsson assignment of the ground state of Cf^{249} is also 9/2−, 734.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
[1] S. G. Nilsson, Kgl. Danske Videnskab. Selskab Mat.-fys. Medd. **29**, No. 16 (1955).

R3. Alpha and Gamma Spectra of U^{235}.* R. C. Pilger,† F. S. Stephens, Jr., Frank Asaro, and I. Perlman, *University of California, Berkeley.*—We have studied the alpha-particle and gamma-ray spectra of U^{235} using a double-focusing magnetic alpha particle spectrograph and NaI(Tl) scintillation gamma ray and coincidence spectrometers. Alpha groups of U^{235} were identified at 4.559 Mev (7%), 4.520 Mev (3%), 4.32→4.37 Mev (84%), and 4.117±0.004 Mev (6%). The distribution at 4.32→4.37 Mev is clearly complex, consisting of three or more alpha groups. Gamma rays were identified at 95 (9%), 110 (5%), 143 (12%), ∼165 (≲4%), 185 (55%), and ∼200 kev (≲4%). The region of the spectrum between 140 and 200 kev was sufficiently complex that other weak gamma rays could be present or the listed intensities could be redistributed slightly. A limit of 0.1% was set on radiations of energy greater than about 250 kev. These data together with some coincidence measurements have been interpreted in terms of three rotational bands whose base levels have energies and Nilsson[1] assignments (I, π, N, n_z, Λ) of 0 kev (5/2+, 633), 185 kev (5/2−, 752), and 390 kev (7/2−, 743).

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
† Now in the Department of Chemistry, University of Washington, St. Louis, Missouri.
[1] S. G. Nilsson, Kgl. Danske Videnskab. Selskab Mat.-fys. Medd. **29**, No. 16 (1955).

R4. Electron-Capture Decay of Ac^{224}.* M. W. Hill, F. S. Stephens, Jr., Frank Asaro, and I. Perlman, *University of California, Berkeley.*—The gamma radiations from the electron-capture decay of Ac^{224} have been examined with NaI(Tl) single crystal and coincidence scintillation spectrometers. The gamma spectra and K x-ray-gamma coincidence spectra show only K x-rays and gamma rays of 133 kev and 217 kev. This indicates population to the 217-kev level in Ra^{224}, which is known to de-excite by gamma transitions of 133 and 217 kev, and has been assigned a spin and parity of 1− as a result of alpha-decay studies of Th^{228}.[1] From the relative intensities of the gamma rays and radium K x-rays, it appears that at least 80% of the electron-capture decay populates this 1− state, with an upper limit of 2% being set on population to states of higher energy. The ratio of the reduced transition probabilities $\gamma 217/\gamma 133$ is calculated to be 0.51±0.05. According to theory,[2] this clearly indicates that the 1− state has $K=0$ and is thus interpreted to be a state of collective motion and a member of the ground-state rotational band. The possible assignments for the ground state of Ac^{224} will be discussed.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
[1] Asaro, Stephens, and Perlman, Phys. Rev. **92**, 1495 (1953).
[2] Alaga, Alder, Bohr, and Mottelson, Kgl. Danske Videnskab. Selskab Mat-fys. Medd. **29**, No. 9 (1955).

R5. Electric Monopole Transitions in Pu^{238} and U^{234}.* I. Perlman, Frank Asaro, B. G. Harvey, and F. S. Stephens, Jr., *University of California, Berkeley.*—Electric monopole transitions in Pu^{238} and U^{234} were seen following the alpha decay of Cm^{242} and Pu^{238}, respectively. An anthracene crystal spectrometer was necessary to register the weak K and $L+M$ lines which occurred in fewer than 1 in 10^6 alpha disintegrations. The $K/L+M$ ratios were 4.5 which agrees with the value 5 given by theory for an EO transition.[1] Each EO transition was shown to lead from an excited 0+ state to the 0+ ground state and to compete with an $E2$ gamma ray from the same excited level to the 2+ state of the ground-state rotational band. This competition will be discussed in terms of the theory. The EO assignment was made by determining minimum values for the conversion coefficients and showing that the high values so obtained could not arise from high multipolarity ($M4$ or above) transitions. The excited 0+ state in Pu^{238} is at 935 kev and that for U^{234}, at 810 kev. The U^{234} state is undoubtedly the same as that previously seen following the beta decay of UX_2.[2,3]

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
[1] E. L. Church and J. Weneser, Phys. Rev. **103**, 1035 (1956).
[2] L. Meitner, *Handbuch der Physik* (Springer, Berlin, 1933), Vol. 22.
[3] Bradt, Heine, and Scherrer, Helv. Phys. Acta **16**, 455 (1943).

R6. Energy of the Isomeric State U^{234m}.* M. C. Michel, Frank Asaro, and I. Perlman, *University of California, Berkeley.*—A study of the energy spectrum of the electrons emitted in the decay of 26.5-min U^{234m} [1-3] has been partially completed using an integral single-retarding-field electrostatic analyzer. The results indicate an essentially continuous spectrum with greatest intensity in the lower energy regions, and an end point of 70.5±1 electron volts. The lack of significant structure is believed to be due to non-nuclear effects of the sample environment, such as energy loss by ionization and secondary electron processes. No effect on the half-life resulting from chemical bonding has been detected. Assuming a transition energy of 75 electron volts (see below) a conversion coefficient of $\sim 10^{21}$ is calculated for the isomeric transition using the observed half-life and a radiative half-life estimated

from the observed gamma lifetime of the similar transition in Pu^{237m}.[4]

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
[1] Frank Asaro and I. Perlman, Phys. Rev. **107**, 318 (1957).
[2] Huizenga, Rao, and Engelkemeier, Phys. Rev. **107**, 319 (1957).
[3] Freedman, Porter, Wagner, and Day, Phys. Rev. (to be published).
[4] Stephens, Asaro, Amiel, and Perlman, Phys. Rev. (to be published).

R7. Decay of Neptunium-238.* R. G. Albridge and J. M. Hollander, *University of California Radiation Laboratory, Berkeley.*—A study has been made of the energy levels of Pu^{238} by an examination of the Np^{238} conversion electron spectrum in high-resolution, permanent-magnet, photographic-recording beta spectrographs. Agreement is found with the general features of the decay scheme proposed by previous workers, but three new transitions are observed and placed in the scheme. These have energies of 885, 943, and 988 kev. The formerly unresolved transitions of ~1030 kev have been resolved into two components, 1027 kev and 1030 kev. Comparisons are made of the experimental relative transition intensities with those predicted from the rules of Alaga *et al.*[1] for transitions depopulating the beta and gamma vibrational bands, and satisfactory agreement is obtained providing the postulate is made that the 940- and 943-kev transitions are of the electric monopole type. From a consideration of the beta-decay ft values the spin and parity value of 3, even is suggested for Np^{238}.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
[1] Alaga, Alder, Bohr, and Mottelson, Kgl. Danske Videnskab. Selskab Mat.-fys. Medd. **29**, No. 9 (1955).

R8. Theoretical Studies of Alpha Decay of U^{233}. Richard R. Chasman and John O. Rasmussen, *University of California Radiation Laboratory, Berkeley.*—The differential equations describing favored alpha decay in the regions of deformed nuclei have been previously derived.[1,2] The present report involves the application of these differential equations to odd-mass nuclei, in particular U^{233}. The calculation dealt with the population of the ground-state rotational band levels of Th^{229}, having spins 5/2, 7/2, and 9/2 by alpha particles of angular momenta 0 and 2. The work was done by numerical integration on an IBM-650 computer. From this work one can compute the phase shift of the $l=0$ wave relative to the $l=2$ wave, going to the 5/2 state of Th^{229}, specifically induced by the nuclear quadrupole deformation; the value obtained for $\theta_2-\theta_0$ being 3°. The calculation is of interest, also, as offering an improvement on the Bohr-Fröman-Mottelson branching relation[3] for the $l=2$ group. An analytic expression for the partial waves in the barrier region of the form $(\alpha+\beta/r^4)G_L$, seems to give good agreement with the intensity predictions.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
[1] J. O. Rasmussen and B. Segall, Phys. Rev. **103**, 1298 (1956).
[2] I. Perlman and J. O. Rasmussen, *Handbuch der Physik* (Springer-Verlag, Berlin, 1952), Vol. 42, Eq. (32.1).
[3] Bohr, Fröman, and Mottelson, Kgl. Danske Videnskab. Selskab Mat.-fys. Medd. **29**, No. 10 (1955), cf. Eq. (5).

R9. Decay of Os^{182} and Os^{182m}.* John O. Newton† and Virginia S. Shirley, *University of California Radiation Laboratory, Berkeley.*—The decay of the electron capturing isotope Os^{182} has been studied with beta- and gamma-ray spectrometers; coincidence measurements have also been made. The ground state of Os^{182} decays with a half-life of 13.5 hours. Transitions which are attributed to its decay have the following energies in kev: 114.44, 145.37, 167.90, 381.8, 477.2, 496.1, 807.8, 852.0, 887.5, and 889.5. The 381.8-kev transition has been shown to be electric dipole and to have a half-life of 8×10^{-9} second. This implies a hindrance relative to the single proton lifetime of 2×10^4; nevertheless the experimental values for the conversion coefficients seem to be consistent with the theoretical values. An isomeric state of Os^{182} having a half-life of 10 hours also has been found. It decays to the ground state of Os^{182} by means of an $M4$ transition of energy 170.7 kev and to states in Re^{182} having excitation energies of 1103 and 1109 kev. A decay scheme will be presented.

* This work was performed under the auspices of the U. S. Atomic Energy Commission.
† On leave of absence from A.E.R.E., Harwell, England.

R10. Al^{26} Decay Scheme.* James M. Ferguson,† *MIT* (introduced by R. L. Mather).—The energies and intensities of the beta and gamma radiations from the long-lived ground level of Al^{26} were studied with scintillation spectrometers. The positron spectrum was obtained using a plastic scintillator with 4π geometry and was found to have a forbidden shape and an end point of 1.160±0.008 Mev. The positrons are in coincidence with a gamma ray with an energy of 1.84±0.01 Mev, which is presumably from the first excited level of Mg^{26}. There is also a weak gamma ray with an energy of 1.10±0.05 Mev, in coincidence with the 184-Mev gamma ray, and with an intensity of 0.05 relative to the 1.84-Mev gamma ray. This would be from the second excited level of Mg^{26}, to which the Al^{26} decays weakly by electron capture. No other gamma rays are observed. It appears that a peak in the pulse-height spectrum at 700 kev is due to scattering effects rather than a gamma-ray photopeak.

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
† Now at the U. S. Naval Radiological Defense Laboratory.

R11. Directional Correlation of the Gamma Rays of Gd^{154}.* G. D. Hickman† and M. L. Wiedenbeck, *University of Michigan.*—Direction correlation measurements have been made on the gamma radiation from the excited states of Gd^{154}. The results of these measurements indicate a spin sequence of $4(Q)2(Q)0$ for the 0.248 Mev −0.123 Mev correlation. Preliminary measurements on the higher excited states indicate a spin of 2 for the 0.998-Mev level, and a spin of 3 for the 1.130-Mev level. These results are in agreement with values proposed by J. O. Juliano[1] on the basis of conversion coefficients measurements. A spin of either 2 or 3 can be assigned to the 1.404 level, with a probable value of 5 for the 1.723 level. Other possible spin assignments for some of the higher excited states will be discussed.

* Supported in part by the Michigan Memorial Phoenix Project and Office of Naval Research.
† Eastman Kodak Fellow.
[1] J. O. Juliano, UCRL-3733 (1956).

R12. Beta-Decay Spectrum of N^{16}.* B. D. Kern,† V. P. Kenney, and G. Brunhart, *University of Kentucky.*—The complex beta-ray spectrum of 7.38-second N^{16} has been investigated with a shaped-field 180-degree magnetic spectrometer. The N^{16} activity was produced by 1.5-Mev deuterons through the reaction $N^{15}(d,p)N^{16}$, using targets of lead nitrate enriched to 64% in N^{15}. Three beta-ray groups are observed, with end point energies of 10.40±0.05 Mev, 4.39±0.07 Mev, and 3.32±0.05 Mev. The relative intensities are in the ratio 28:54:18, and the $\log ft$ values are 6.2, 4.0, and 4.4. The beta-ray relative intensities are not entirely in agreement with observed gamma-ray relative intensities, but are more nearly so than was reported earlier.[1] The 10.40-Mev group is shown by its unique shape factor to proceed as a first-forbidden $\Delta J=2$ (yes) transition and definitely not as a $\Delta J=0$ (yes)

transition. The decay of the other two groups is allowed. The ground state of N^{16} is uniquely designated as a 2^- level.

* At present at the U. S. Naval Radiological Defense Laboratory, San Francisco, on leave of absence from the University of Kentucky.
† This work was supported in part by the U. S. Atomic Energy Commission.
[1] P. W. Morton and H. W. Lewis, Bull. Am. Phys. Soc. Ser. II, 2, 286 (1957).

R13. Precision Determination of Some Energy Levels in Fe^{57}, Zn^{67}, and Tc^{99}.* E. L. CHUPP, J. W. M. DUMOND,† F. J. GORDON, R. C. JOPSON, AND HANS MARK,‡ *University of California Radiation Laboratory, Livermore.*—The 7.5-Mev deuteron beam of the A-48 linear accelerator has been used to produce strong sources of the radioactive nuclides Co^{57}, Ga^{67}, and Tc^{99m} by means of the (d,n) and (d,p) reactions on Fe^{56}, Zn^{66}, and Mo^{98}. Co^{57} and Ga^{67} decay by K-capture to excited states in Fe^{57} and Zn^{67}. Tc^{99m} is made by the reactions $Mo^{98}(d,n)Tc^{99m}$ and $Mo^{98}(d,p)Mo^{99}$ in which Mo^{99} subsequently decays to Tc^{99m} with a half-life of 67 hours. Appropriate sources containing these nuclides were exposed in the high-resolution bent-quartz-crystal spectrograph previously described,[1] and photographic spectra of the strongest nuclear gamma rays emitted by these sources were obtained. The plates were calibrated with x-rays and gamma rays of known wavelengths. The energies (in kev) of the various levels measured are: Fe^{57}, 122.05±0.04 and 136.40±0.06; Zn^{67}, 93.26±0.04 and 184.46±0.27; and Tc^{99} 140.52±0.08. The cascade gamma ray between the two levels in Zn^{67} was also observed and its energy was determined as 91.22±0.03 kev, in good agreement with the difference (91.20±0.28 kev) between the values quoted above for this isotope.

* This work was done under the auspices of the U. S. Atomic Energy Commission.
† Department of Physics, California Institute of Technology, Pasadena, California.
‡ Now at the Department of Physics, Massachusetts Institute of Technology, Cambridge, Massachusetts.
[1] Chupp, Clark, DuMond, Gordon, and Mark, Phys. Rev. 107, 745 (1957).

R14. Energy Systematics of Even-Even Nuclei with $30 \leq N \leq 50$.* D. J. HOREN AND W. E. MEYERHOF, *Stanford University.*—We have recently reinvestigated the decay schemes of Cu^{66} and Ge^{66}. This work, as well as proton-[1] and neutron-[2]induced excitation of Zn^{64}, Zn^{66}, and Zn^{68}, indicates that for these nuclei the energy ratio of the second-excited to the first-excited state (E_2/E_1) is less than two. At present there are known seven even-even nuclei with $E_2/E_1 < 2$ and one doubtful case with $E_2/E_1 > 2$ in the region $30 \leq N \leq 40$, neglecting the 0+ excited states in Ge^{70} and Ge^{72}. There are known four nuclei with $E_2/E_1 > 2$ and one with $E_2/E_1 < 2$ in the region $42 \leq N \leq 50$.

* Supported in part by the joint program of the Office of Naval Research and the U. S. Atomic Energy Commission.
[1] C. E. Weller and J. C. Grosskreutz, Phys. Rev. 102, 1149 (1956).
[2] R. M. Sinclair, Westinghouse Research Report 60-94511-6-P12 (1956).

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Second Announcement of the 1958 Annual Meeting

The 1958 Annual Meeting of the American Physical Society will be held in New York City on Wednesday, Thursday, Friday, and Saturday, January 29, 30, 31, 1957, and February 1, 1958. Sessions will be held in the Hotel New Yorker and in the Manhattan Center. The official hotel is the New Yorker. Make your reservations early and do not fail to say that you are coming to our meeting.

Deadline date for this meeting is Friday, November 15, and abstracts are to be sent to the office of the Society at Columbia University, New York 27, New York. This deadline date has already appeared in the "calendar of prospective meetings" in the June and September issues of this *Bulletin* (a remark here inserted because this issue might possibly be delayed in publication until the date is past).

Preliminary Announcement of the 1958 March Meeting at Chicago

The **1958 March meeting** of the American Physical Society will be held in Chicago, at the University of Chicago and under the auspices of the Institute for the Study of Metals of that University, on **Thursday, Friday, and Saturday, March 27, 28, and 29, 1958.** This will continue the tradition of the March meetings particularly favored by our Divisions of High-Polymer Physics and Solid-State Physics. All reservations of hotel rooms are to be made through the Hotels Windermere, 1642 East 56th street, Chicago 37, Illinois. It is essential to mention the Society in your letters asking for room reservations. After the accommodations in the Windermere itself are fully bespoken, Hotels Windermere will assume the responsibility of placing our members at other hotels of the region. Deadline date is Friday, January 17, 1958, and abstracts must be received not later than this date at the office of the American Physical Society, Columbia University, New York 27, New York.

MEETINGS AND DEADLINES FOR THE SEASON 1957–1958

Place	*Meeting dates*	*Deadline date*
Stanford, California	December 19–21	past
New York	January 29–February 1, 1958	past
Chicago	March 27–29	January 17
Washington	May 1–3	February 21
Ithaca, New York	June 19–21	April 18
Vancouver,* British Columbia	August 26–28	June 27

* Abstracts for the Vancouver meeting are to be sent to W. A. NIERENBERG, University of California, Berkeley 4, California, and must reach his office not later than the corresponding deadline date.

Abstracts for the other meetings listed above are to be sent to KARL K. DARROW, American Physical Society, Columbia University, New York 27, New York, and must reach his office not later than the corresponding deadline date. Take note that abstracts mailed the day before deadline day often fail to arrive in time: the last postal delivery of the day usually comes to our office before 2 P.M. Allow at least two days for abstracts sent by airmail from points east of the Mississippi, and longer for those sent from farther west. To avoid chance of confusion, please do not send an abstract for any meeting until the deadline date of the previous meeting is at least five days past. *The privilege of contributing papers to meetings of the American Physical Society is restricted to the members of the Society and to nonmembers whose papers are sponsored by members.*

RULES AND INSTRUCTIONS FOR THE PREPARATION OF ABSTRACTS

The Council has ordered that abstracts shall be not longer than two hundred (200) words or the equivalent thereof. In reckoning equivalence, a footnote is equated to ten words; each line in a table to ten words; a "display" formula—one that requires a line to itself—is an expensive luxury equated to forty words.

Two copies of each abstract must be sent to the appropriate office. They must be typewritten; one must be an original, the other may be an original or a carbon copy. *They must be double-spaced:* single-spaced manuscripts are too crowded to permit the editorial markings to be made with ease and clearness. Each abstract must be confined to a single page: if it is too long for a single page it is too long to be printed. *If we receive an abstract typed on two pages, we print only its first page.* Write each abstract as a single paragraph: the suppression of paragraphs costs time and labor to the editors. Do not use very thin paper; a sheet of very thin paper may cause extraordinary trouble when mixed with sheets of reasonable thickness. Look at the abstracts in this *Bulletin* to see how the title of the paper and the name of the author are to be arranged, and follow the example. Issues of the *Bulletin* are always appreciably delayed because the editors have to do what the authors should have done.

Remember the rule of the Council that, if an author submits more than one abstract, all but one must go onto the Supplementary Programme. In enforcing this rule, an abstract is credited to the author whose name appears first in the by-line.

It now becomes an expensive business to make any change in an abstract, even the smallest, after the abstract has gone to press. By order of our Council "A change in an abstract will be permitted only at the discretion of the Secretary or his deputy, and only if TEN DOLLARS is enclosed with the letter in which the change is requested." As heretofore, an abstract will not be withdrawn from proof unless the asker sends ten dollars with his request.

Proceedings of the American Physical Society

Minutes of the 1957 Spring Meeting Held at Washington, April 25, 26, and 27, 1957

There is a saying to the effect that happy times do not make for exciting history. The skill of our long-experienced and sometimes severely tried Washington Local Committee is such that any obstacles that are not sheerly unsurmountable (such as losing desired auditoriums to other conventions, as happened in 1956 but not in 1957) are surmounted before the meeting begins and the members never hear of them. Everything happened with the smoothness that betokens hard work and skillful organization. The 406 contributed papers exceeded, though by only two, the greatest number at any previous meeting. The registration amounted to 1732, a figure which cruelly suggests that there may have been some who managed to find the sessions but walked blindly past the registration desks. The banquet was attended by a mere 223, who enjoyed the privilege of hearing L. V. Berkner.

Those who by their work in or for the Local Committee made this meeting go so smoothly and well are R. D. Huntoon, the Chairman; D. F. Bleil, Richard Elmendorf, W. C. Hall, A. I. Mahan, J. H. McMillen, S. F. Singer, L. Slack, H. Tatel, and W. R. Tilley. To Mrs. Francis M. Defandorf the ladies owe opportunities for a visit to the Mosque, one to the National Cathedral, and a drive in and around Washington. Our thanks to all of these!

Errata Pertaining to Abstracts B6, CA5, H13, HA1, SA1, W4, and Z2 of the 1957 Washington Bulletin (Series II, Volume 2, No. 4)

B6, by L. G. Lang and N. C. Hien. In line 10, instead of "agrees" read "disagrees."

CA5, by Richard A. Ferrell. Instead of the second sentence read, "Because the mesic charge of an antinucleon is opposite that of a neucleon for both PS and PV coupling, the annihilation of slow antiprotons in hydrogen does not distinguish between these two types, but does distinguish between *S*-wave and *P*-wave annihilation." Instead of the last sentence read, "For *P*-wave annihilation the situation would be reversed and the decay would be mainly into odd numbers of pions."

H13, by O. Chamberlain, T. Elioff, E. Segrè, H. Steiner, R. Weingart, C. Wiegand, and T. Ypsilantis. In line 13, instead of "2 by 2 by 2 in." read "2 by 2 by 2 ft."

HA1, by G. R. Keepin. Instead of the title as printed, read "Delayed Neutrons from the Fission of Uranium-235, Uranium-233, Plutonium-239, Uranium-238, Plutonium-240, and Thorium-232."

SA1, by Etsuro Sawaguchi and Melvin L. Charters. In line 1, instead of "$PB_\lambda Ca_{1-\lambda}TiO_3$" read "$Pb_\lambda Ca_{1-\lambda}TiO_3$." In line 3, instead of "$\lambda=0.05$" read "$\lambda=0.5$."

W4, by M. A. Clark and J. W. Knowles. In line 4, instead of "0.06% resolution in a NaI scintillation spectrometer" read "0.06% resolution, in a NaI scintillation spectrometer." In line 7, instead of "maximum energies of 56 ± 15" read "maximum energies of 560 ± 15."

Z2, by Simon Foner. In line 14, instead of "single coil following higher magnetizing field" read "single coil allowing higher magnetizing fields."

Minutes of the Summer Meeting in the East Held at the University of Notre Dame, Notre Dame, Indiana, June 20, 21, and 22, 1957

THE 1957 Summer Meeting in the East was held on June 20, 21, and 22 at the University of Notre Dame, Notre Dame, Indiana. These summer meetings in the East are usually the small, intimate, leisurely meetings which are similar to the old Physical Society meetings, before the subject became so popular.

The registration at this meeting was 228. There were 68 contributed papers and 24 invited papers. A large fraction of the papers of the meeting were from the Division of Electron Physics. The Chairman of the Local Committee, Professor J. W. Mihelich of the Department of Physics of the University of Notre Dame, did an excellent job in arranging everything for the Society, including the weather. The Society was fortunate in having relatively cool, dry weather during the meeting, although Notre Dame had heat waves both before and after the meeting.

A cocktail party was given at the Student Center on Friday afternoon by the University of Notre Dame for the members of the American Physical Society. Liquid refreshments were plentiful and enjoyed by everybody. The banquet of the Society was held at the University dining hall after the cocktail party, with attendance of about 125. The first of the two speakers of the evening was Reverend Theodore M. Hesburgh, President of Notre

Dame, who contributed some thought-provoking ideas in his talk entitled "Science and Theology." The second speaker was Dr. George B. Collins, of Brookhaven National Laboratory, who described the alternate gradient focusing 25-Bev synchrotron which is now being designed at Brookhaven. W. W. Havens, Jr., presided. The Society owes a vote of thanks to Professor Mihelich and also to Professor H. J. Bolger and to the University of Notre Dame for being such excellent hosts at this meeting. This was the first meeting that the Society has had at the University of Notre Dame, and we who attended hope that it will not be the last.

A list of those elected to membership follows.

Elected to Membership in June, 1957: Richard R. Addiss, Jr., *Igor Alexeff, *Sayed Ahmad Ali, *Saburo Amai, *Wayne P. Amsbury, *Albert Arakengy, Russell James Arave, *Charles Asawa, Elizabeth Avera, Joseph B. Aviles, Jacob R. Baer, *Wilson M. Barnes, Jr., *William Lee Barr, Richard E. Beekman, Herbert L. Bernstein, *Hyman Bernstein, *Arthur Bierman, Donald J. Blanchard, Roger S. Boyd, Shelia Brenner, *Alfred Büchler, Robert Ellwood Buck, Philip G. Burke, Nathan Frank Cardarelli, James H. Carmichael, *George B. Chadwick, George Thomas Chapman, *Samuel Estelle Chappell, *Marvin Chester, Peter F. Chester, *Herman W. Chew, Raymond Lu-Po Chuan, John Walter Clark, *Eugene J. Clothiaux, Ralph R. Coltman, Jr., *Eustratios Constantinides, *Bernard R. Cooper, Carl M. Copenhaver, *Roberta U. Cordova, *Julian A. Crawford, Elmo E. Crump, Arthur C. Damask, Richard D. Daniels, Dana H. Dickey, David W. Dilley, *Patrick David Doherty, *Ben F. Edwards, W. Luther Eggman, *Raymond C. Elton, John H. Enns, K. B. Fenton, Raymond C. Ferguson, Paul C. Fletcher, Harry R. Foster, *Allen K. Garrison, *J. N. Laurie Gauvin, Martin D. Gibbons, *Gordon L. Goodman, *George S. Gordon, Jr., Robert B. Gray, James H. Greiner, *Edward P. Greene, Feza Gürsey, Epimenides D. Haidemenakis, George Lincoln Hall, Stephen H. Hanauer, Misao Hasegawa, *William S. Hellman, *Michael G. Henderson, *Allen Henkins, *Gary Herling, *Donald R. Hesser, *John R. Hiskes, P. E. Hodgson, *Leslie E. Hoffman, *Norman Jacob Horing, *Richard W. Huggett, *James E. Hurt, Robert E. Hysell, Kozo Ishikawa, George L. Jenkins, *Chester C. Johnson, Francis S. Jones, Frank E. Jones, *Leo Kadanoff, *David Kahn, *Peter B. Kahn, *Robert W. Kedzie, William M. Keely, *William J. Kernan, Jr., Young C. Kim, *Clyde W. Kimball, Heinz Koehler, *Robert J. Kolenkow, *Jerome Kristian, Bobby Lee Landrum, *T. P. Lang, Jr., *Kun Syung Lee, *James J. Leigh, Richard L. Liboff, *Robert W. Lide, *Donald C. Lindley, Henry F. Lockwood, Alexander Mackenzie, Abraham Many, *George E. Marks, Edward A. Martin, Thomas J. Matcovitch, *Dean W. Maurer, *James W. Mayer, *Maclyn McCarty, Jr., Vincent McClusky, Frank B. McDonald, Rosemary T. McGinnies, Edward P. McLaughlin, Emmanuel Meeron, James J. Menard, *Norman J. Meyer, Norman J. Meyerhoff, R. David Middlebrook, Marian Miesowicz, *Raiq S. Musa, Aaron W. Newman, *Austin A. O'Dell, Jr., Francis W. O'Dell, Giuseppe Oppo, Vernon Ozarow, Dale R. Palmer, *Paul E. Phillipson, *Arnold David Pickar, Donald A. Pitt, Luigi M. Preziosi, *Robert A. Profat, Peter Putnam, *Victor Rehn, Edwin D. Reilly, Jr., *Eugene Rettig, Paul J. Ring, *Edwin M. Roberts, III, Hans Juergen Rose, Peter Henry Rose, *Gerd M. Rosenblatt, Herbert Rubenstein, *Rainer K. Sachs, *Guido Sandri, *Peter Eli Schlein, *Frank Scherb, *James H. Scofield, Kenneth B. Scow, Herbert John Shaw, Henry Shucker, *Bernard Smilowitz, Jack T. Smith, Robert B. Smith, Sven Oluf Sorensen, Leo Steg, Lewis L. Stone, Robert L. Strong, *Jan Emil Stroth, *George Allan Swartz, *Robert T. Taylor, *Archie Temperley, *Judith K. Temperley, *Robert William Terhune, *George Tessler, Martin W. Teucher, Randal H. Thomas, Clark Tyler Thompson, Joseph S. Titus, Alvin R. Topfer, *Laird Charles Towle, Hilbert J. Unger, Milton D. Van Dyke, Karel M. Van Vliet, Gianni Venturini, Rudolph R. Verderber, *James Frank Verdieck, *Frank L. Vernon, Jr., *Gershon Vincow, *Frederick Ludwig Vook, *Gray D. Ward, Margaret Ellen Way, *John A. Weaver, Thomas J. Webb, *Richard Flanders Weeks, Clarence P. Welty, *Kenneth Alan Wickersheim, Clifford Wight, *Hubert W. Wilson, Joseph C. Yater, Thomas Young, *Taek-Soon Yoon, *Suck Koo Yun, and *Daniel E. Zwanziger.

* Student.

W. W. Havens, Jr.
Deputy Secretary
Columbia University
New York 27, New York

Errata Pertaining to Abstracts L5 and L11 of the 1957 Notre Dame, Indiana, Bulletin (Series II, Volume 2, No. 5)

L5, by Lawrence Rosler and Charles A. Fenstermacher. In line 14, "the second excited level is a 3+ level" should read "the second excited level is a 4+ level, or a 3+ level with $\delta = -0.2 \pm 0.04$."

L11, by Joseph G. Barredo. The title of this abstract should read "Nuclear Model." In line 7, "de Broglio" should read "de Broglie."

Minutes of the Winter Meeting on the West Coast
Held at the University of Colorado,
Boulder, Colorado,
September 5, 6, and 7, 1957

THE 1957 Summer Meeting on the West Coast of the American Physical Society was held in Boulder, Colorado, on Thursday, Friday, and Saturday, September 5, 6, and 7. This was the first time the Society has ever met at the University of Colorado, and it was a very pleasant and profitable occasion. The beautiful dormitories and meeting rooms of the University added a great deal to the functioning of the meeting.

There were 26 invited papers and 122 contributed papers, and a negligible number of contributed papers were read by title. We owe special thanks to Professor J. R. Zacharias for a most interesting symposium on Time Frequency Standards.

There were 376 registrations and 240 in attendance at the banquet. The Local Committee arranged a number of mountain trips, including a Chuckwagon Dinner on Flagstaff. The banquet was preceded by a cocktail party at the country club. Dr. A. V. Astin was the principal speaker at the banquet and spoke on "Scientists and Public Responsibility." President J. Q. Newton of the University of Colorado greeted the Society at the banquet.

The local chairman for the meeting was Professor A. B. Weaver, Chairman of the Department of Physics at the University of Colorado, who was especially responsible for a meeting that was beautifully run with very careful attention paid to detail. Particular mention should be made of the efforts of Dr. R. L. Powell, who represented the National Bureau of Standards at Boulder, the joint hosts.

W. A. Nierenberg
Local Secretary for the Pacific Coast
University of California
Berkeley 4, California

Important Notice to Members and Fellows of the American Physical Society

A new Membership List of the American Physical Society will be issued in 1958, and it is highly desirable that this be as nearly complete and accurate as possible. Shortly after January 1, 1958, you should receive by first-class mail, in a window envelope, a return addressed postal card bearing your name and address of present record, together with instructions for its immediate return amended as necessary. If you do not receive this postal card before January 31, 1958, notify the undersigned of your name and address as you wish them to appear in the Membership List. If your professional affiliation does not appear in your address, this additional information is requested.

Shirley L. Quimby
Pupin Physics Laboratories
Columbia University
New York 27, New York

THE INDEX

TO THIS VOLUME HAS BEEN REMOVED FROM THIS POSITION AND PLACED AT THE BEGINNING OF THE FILM FOR THE CONVENIENCE OF READERS.

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The American Physical Society

OFFICERS OF THE SOCIETY FOR 1957

President	H. D. SMYTH	Princeton University
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Local Secretary for the Pacific Coast	W. A. NIERENBERG	University of California, Berkeley
Deputy Secretary	W. W. HAVENS, JR.	Columbia University